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UNIVERSITY OF ALBERTA

BODY CONDITION OF MALLARDS (*ANAS PLATYRHYNCHOS*) OVERWINTERING IN EDMONTON, ALBERTA.

by

IWONA PAWLINA

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH IN
PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE

DEPARTMENT OF ZOOLOGY

EDMONTON, ALBERTA
FALL 1991

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The undersigned certify they have read, and recommended to the Faculty of Graduate studies and Research for acceptance, a thesis entitled Body condition of mallards (*Anas platyrhynchos*) overwintering in Edmonton, Alberta submitted by Iwona Pawlina in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE.

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Date: June 21 1991

Abstract

The body condition of mallards (*Anas platyrhynchos*) overwintering on the North Saskatchewan River in Edmonton, Alberta was investigated to determine the extent to which it declined and the possible consequences of this decline on the reproductive potential of these birds in the following breeding season.

Each autumn a small proportion (ca. 1.5%) of the continental population of mallards remains to overwinter in Alberta (53°N), well north of traditionally-used wintering grounds, probably in response to a growing availability of water kept open artificially post freeze up. Such birds attempting to overwinter at northern latitudes must cope with lower temperatures and food availability (more snow) than mallards overwintering farther south.

This wild population lost weight (22-30%) between early winter and early spring, suggesting that these birds were almost reaching the critical body weight and condition. Most of the loss was the result of a decline in lipid reserves (66-92%); some of the loss was due to decline in protein reserve (9-41%). Analysis of visceral morphology of these birds showed that they were unable to compensate for either low quality of food by switching diet, or low quantity by increasing food intake. The weight of gonads in early spring, 50-95% lower in compare to gonads of birds from southern sites, suggests delayed sexual development in these wild mallards. Also, because of the poor body condition, at least in juveniles, the molt was delayed.

The sex ratio was biased in favor of males (71:29). The percentage of juveniles in this population (84%) was very high with males exceeding the females. The biased sex ratio was probably caused by the differential emigration of sexes on the onset of winter. The large number of juveniles may have reflected good breeding season resulting in large number of young birds produced from renesting attempts. The mild temperatures in autumn may not have stimulated these juveniles to migrate.

The birds which survived the winter season in Edmonton were in very poor body condition, apparently unable to accumulate the necessary lipid reserves for spring migration and subsequent reproduction. Hence such overwintering birds may have entered an ecological trap and as a consequence became an ineffective component of the breeding continental population of mallards.

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I. Introduction

Each autumn waterfowl leave their northern breeding grounds and migrate south to traditionally-used wintering grounds where they avoid unfavourable winter conditions that prevail at more northern latitudes. A proportion of the continental population of mallards (*Anas platyrchynhos*) however, will remain north of traditionally-used wintering grounds providing open water and food are available (Bellrose 1980, Sugden et al. 1974). Winter nutrition is very important to mallards and other waterfowl because it can affect their winter survival and future reproductive success by influencing the timing of behaviourial events in the reproductive cycle.

Wintering waterfowl allocate energy not only to routine activities such as foraging, flying, swimming, walking (Prince 1977, Rabenberg 1982) but also to thermoregulation (Prince 1977), molt (Heitmeyer 1987,1988a), formation and maintenance of pair bonds (Bellrose 1980, Brodsky and Weatherhead 1985, Pattenden and Boag 1989b), and development of adequate lipid reserves for spring migration (Bellrose 1980) and reproduction (Ankney and MacInnes 1978, Krapu 1981, Pattenden and Boag 1989b, Raveling 1979). Failure to meet any of these energy needs may have serious repercussions on the individual's reproductive potential.

Such birds attempting to overwinter at northern sites must cope with lower temperatures and more snow than mallards returning to traditional wintering grounds. Low temperatures at the northern wintering grounds increase the individual's energy demands for thermoregulation. They also decrease the availability of aquatic habitat as open water freezes over, and of food, as the snow covers feeding grounds. As a consequence birds overwintering at northern latitudes are faced with the challenge of increased energy demands when food resources are often limited.

Wintering in close proximity to breeding grounds in Alberta could be advantageous to waterfowl if they avoid some of the energy costs associated with a long migration. They could also reach their breeding grounds earlier than ducks undergoing regular spring migration from the south, assuming that they initiated migration at these same time, and consequently could have access to optimal territories.

But, as Brodsky and Weatherhead (1985) suggested, early arrival on the breeding grounds is not that important if the birds are not physiologically ready to reproduce, either lacking a mate and/or the necessary energy reserves.

Body condition is the state of individual's energy reserves (fat and protein) accumulated to meet energy demands for body maintenance, migration, molt, and activities such as courtship and pair formation. Paired males carrying large lipid reserves to the breeding grounds may be able to reduce their food intake and hence devote more time to defending foraging site for mates (LaGrande and Dinsmore 1988). Paired females which had accumulated lipid reserves in winter would be able to forage for aquatic invertebrates in early spring (source of proteins essential for egg formation) rather than for high energy foods required for body maintenance (Krapu 1981, LaGrande and Dinsmore 1988, Swanson et al. 1985). Furthermore, both sexes, when in good condition, would be able to cope with possible food shortages at the onset of spring on the breeding grounds (Swanson et al., 1985).

Body weight has been used as indicator of body condition (Heitmeyer 1988a, Whyte et al. 1986, Whyte and Bolen 1984). Others have used body weight corrected by some structural measurement such as wing length to eliminate variations resulting from structural differences among individuals (Hepp et al. 1986, Gordon 1981, Owen and Cook 1977, Ringelman and Szymczak 1985).

Body weights of mallards overwintering on traditional grounds, assumed not to be facing any food stress, normally fluctuate over the winter season declining in January and increasing to relatively high levels in late February and March, just before spring migration (Folk et al. 1966, Owen and Cook, 1977). These high spring weights suggest that birds leaving the wintering grounds in March are in good body condition with large accumulated energy reserves.

Krapu (1981) reported that mallards arrive on breeding grounds with relatively large body weights despite the costs of migration suggesting that they were able to maintain or acquire reserves throughout the spring migration.

Nevertheless, acquiring reserves during spring migration or on the breeding grounds would still result in lower reproductive potential if birds were energy-stressed on wintering grounds (Pattenden and Boag 1989b).

Bonnett and Bolen (1978) documented strong relationships among body weight, endogenous fat reserves and body condition. Fluctuations in body reserves result mainly from metabolisation of lipid reserves that occur during cold weather and food shortages (Whyte et al. 1986). In addition to lipid metabolisation during extreme thermal stress, ducks may even utilize protein as a source of energy (Raveling 1979, Reinecke et al. 1982).

Some fluctuation in body weight could be caused by changes in size of digestive organs (Heitmeyer 1988b, Kehoe et al. 1988, Miller 1975, Whyte and Bolen 1985), changes that may indicate metabolisation of protein (Raveling 1979). Thus, to understand the complexity of energy balance in wintering waterfowl it is necessary to examine both their metabolic reserves and morphology.

Despite the importance of the winter season to waterfowl and the growing interest in waterfowl winter physioecology this stage of waterfowl yearly cycle is relatively poorly understood (Weller and Batt 1988). Most research on winter ecology of waterfowl has concentrated on their traditional southern wintering grounds, whereas waterfowl wintering at more northern latitudes have remained largely unstudied. Except for work of Sugden et al. (1974) and Pattenden and Boag (1989a, 1989b) there is, to my knowledge, no other literature on the status of waterfowl overwintering North of 50°N in continental north America.

Pattenden and Boag (1989b) demonstrated the importance of energy balance for overwintering birds. Birds faced with an energy deficit appear less able to contribute to the next generation than birds that were not so stressed. This raises a question about the fate of mallards trying to overwinter north of traditional wintering sites. Are these birds entering an ecological trap that will prevent them from contributing to the next generation despite potential survival into the next season ?

In an attempt to answer this question, I examined the effect of harsh winter weather on body condition of mallards overwintering in Edmonton, Alberta, and on their ultimate fate.

The results of my research are presented in four chapters. In Chapter II I examined effects of weather on body weight, condition and survival of mallards overwintering at northern latitudes by looking at changes in body weight and condition indices. In Chapter III I documented changes in body composition of mallards during the winter season at northern latitudes. In Chapter IV I examined the relationship between changes in visceral morphology of overwintering mallards in relation to nutrient reserves, sexual development, and molt intensity. In Chapter V I integrated the results and discussed the relationship between body condition, survival, and breeding potential of mallards overwintering at nontraditional northern wintering grounds.

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II. Effect of weather on body weight, condition, and survival of mallards on nontraditional northern wintering grounds.

Introduction.

Body condition reflects the status of an individual bird's energy reserves (lipids and proteins), used in meeting energy demands for body maintenance, including molt, for migration, and for reproduction, including pair formation. Fluctuations in body reserves of waterfowl are correlated closely with fluctuations in body weight (Blem 1976, Miller 1986, Raveling 1979, Reinecke et al. 1982); thus, body weight is a good index of body condition (Heitmeyer 1988, Whyte and Bolen 1984b, Whyte et al. 1986). This index can be improved by including some structural measurement, such as wing chord length, to correct for structural differences among individuals (Gordon 1981, Hepp et al. 1986, Owen and Cook 1977, Ringelman and Szymczak 1985, Whyte and Bolen 1984a).

In waterfowl, body weights and energy reserves (mainly lipids) fluctuate over winter season despite the availability of high quality food (Pattenden and Boag 1989b, Whyte and Bolen 1984a, Whyte et al. 1986). Body weights of mallards (*Anas platyhrynchos*) and other waterfowl usually reach their maxima between September and November, decreasing to minima in February before increasing again just before the spring migration (Folk et al. 1966, Owen and Cook 1977, Pattenden and Boag 1989b, Whyte and Bolen 1984a). These fluctuations could be attributed to a combination of weather conditions (Delnicki and Reinecke 1986, Reinecke et al. 1982) and energy expenditure for body maintenance (Prince 1977), molt (Heitmeyer 1988), pairing (Brodsky and Weatherhead 1985, Heitmeyer 1988, Pattenden and Boag 1989b), and migration (Bellrose 1980). Yet captive mallards, in southern Alberta (51°N), with unlimited access to high energy food and low temperatures showed at first some fluctuations and then steady decrease in body weight between December and March suggesting low temperature and perhaps some form of endogenous rhythm controlling changes in winter body condition (Pattenden and Boag 1989b).

Wild mallards, overwintering in Edmonton (53°N), north of traditional wintering ranges, should show an even greater response to harsh winter conditions than the captive birds because the former were exposed to the additional potential stresses of predator avoidance and daily flights in search of food.

Each sex-age group may respond differently to common weather conditions on the wintering grounds. Males are larger and heavier than females and adults are larger and heavier than juveniles (Delnicki and Reinecke 1986, Miller 1986). Juvenile females usually have the lowest weights and survival potential among all age-sex groups (Whyte and Bolen 1984b). Age and early winter physical condition of mallards and other waterfowl influence their overwinter survival (Haramis et al. 1986, Hepp et al. 1986). Similar observations were made by Conroy et al. (1989) for female black ducks (*Anas rubripes*).

Pattenden and Boag (1989a) reported a male-biased sex ratio among mallards overwintering in Edmonton (53°N). Similar ratios were observed by Sugden et al. (1974) for mallards overwintering in Calgary (51°N) and Jorde et al. (1984) for mallards in Nebraska (42°N). Pattenden and Boag (1989b) concluded that the sex ratio, which favored males in the Edmonton population, was established in autumn through differential emigration of the sexes; during one winter when conditions were harsher this ratio became even more biased in favor of males as the winter progressed, presumably because females died at rates higher than males.

Jorde et al. (1984) observed that the number of immature birds and adult females in a population wintering in Nebraska was greater during a mild winter than during cold winter. Therefore, considering the severity of winter conditions prevailing on northern wintering sites (eg. at Edmonton), one would predict that mainly adult males which have the highest probability of survival would attempt to overwinter at such northern latitudes. This study was undertaken to determine the body condition of mallards overwintering in Edmonton based on their body weights during the season, to assess their reproductive potential, and to examine the sex and age structure of this population.

Study area and methods.

The study was conducted during the non-breeding season, from November 20, 1989 to March 15, 1990, on the North Saskatchewan River in Edmonton, Alberta (53°35'N 114°30'W). Overwintering mallards used a stretch of open water in the river, maintained by the warm effluent from an electrical power generation station, waste water treatment plant, and refineries. In addition to the river these birds used nearby agricultural fields as feeding areas.

The winter season was subdivided into four blocks of time: early winter (Nov.3-Dec.5), mid-winter (Dec.6-Jan.5), late winter (Jan.6-Feb.8), and early spring (Feb.9-March 15). During each block of time mallards were captured on continuous bases (at least five days a week) using a swim-in live-trap baited with ca. 10kg of barley. The trap was usually closed on weekends to avoid exposing the trapped birds to additional stresses caused by the presence of city residents walking or skiing along the river. The number of mallards foraging in close proximity to the trap (< 50m) was counted on each visit to the trap to establish if the birds associated with the trap site were a representative sample of the total population on this wintering site. The trap was emptied twice daily: in the morning and in the evening. The captured birds were removed from the trap and held in darkened box indoors for 7 hours during the day or ca. 12 hours overnight. This allowed the plumage to dry and food in the gut to be eliminated, after which the birds were weighed to the nearest 10g on 2500g Pesola spring scale, banded with an official U.S. Fish and Wildlife aluminium band, and released. Total of 95 mallards, which were not previously banded, were sacrificed over the season with a lethal dose of chloroform for body composition analysis (see chapter III).

Determination of age of birds was based on the presence or absence of the bursa of Fabricius (Hochbaum 1942) and feather characteristics (Krapu et al. 1979). The latter was also used to determine sex. Tarsus length was measured with a vernier caliper to the nearest 0.01cm and wing length, with a ruler to 0.1cm.

These data were used to calculate a Condition Index using the following formulas:

Condition Index (CIW)=Body Weight/Wing Length, and

Condition Index (CIT)=Body Weight/Tarsus Length.

The known lipid and protein contents from the body composition analysis were used to determine which of the condition indices (CIW, CIT, body weight) was a better predictor of body condition of the overwintering mallards (see chapter III).

Some birds were found dead during the winter, either along the shore of the river, or inside the trap. All dead birds were collected for laboratory analysis or send to the Animal Health Division, Veterinary Laboratory in Edmonton to determine the cause of death. Only those for which the loss of body condition was the cause of death were included for discussion in this chapter.

Meteorological data were obtained from Environment Canada at the Municipal Airport in Edmonton.

Data analysis.

The severity of the winter season of 1989-1990 was assessed by comparing the mean winter temperatures in that year with the expected mean temperatures for the same period based on long-term weather data. I used the Kolmogorov-Smirnov Two-sample Test for this comparison (Sokol and Rohlf 1981).

If an individual was trapped more than once during a block of time the average weight was calculated and used in analyses to avoid problems arising when an individual contributes more than one observation to the data set (Machlis et al. 1985).

To compare differences in body weight among blocks of time within each sex-age group, I used a multiple comparison Tukey's studentized range test (procedure GLM, SAS Institute Inc. 1975).

To determine if the weight loss differed significantly between age groups and between sex groups, I used the G test for independence .

I performed an analysis of covariance (ANCOVA), based on type III sum of squares (procedure GLM, SAS Institute Inc. 1975), with time as a covariate, to compare the regression slopes of body weight over time among sex-age groups. Results were considered nonsignificant if the *P* value exceeded 0.05.

The date was transformed to a number starting with November 20, 1989 as day number 1 of the season.

Results

1. Weather conditions

The winter of 1989-90 in Edmonton was mild. Except for the month of October when the daily mean temperatures were not significantly different from the long-term mean ($P>0.05$), the temperatures over the rest of the winter season of 1989/1990 were between 0.1 and 6.6°C higher ($P=0.01$) than predicted from the long-term mean.

During the months of December, January, and February the birds were exposed to three cold snaps, each lasting on average 1 week when temperatures ranged between -18°C and -30°C (Figure II-1). Snow accumulated gradually between December and February, reaching a maximum depth of 15 cm on February 15 (Figure II-1). The total snowfall was lower than expected.

2. Sex and age ratio

A total of 1124 mallards was trapped and handled between November 20 and March 15 on the North Saskatchewan River in Edmonton. Of these 575 ducks were measured, banded and released. An additional 95 mallards, selected randomly from the captured sample, were measured and sacrificed for carcass analysis. The remaining 454 birds were recaptures of individuals already banded and previously released.

Overall, ca. 16% of the total overwintering population (4300 birds; based on The Christmas Bird Count) was handled throughout the winter. Of 670 ducks trapped 21 (3.4%) individuals were adult females, 159 (25.6%) were juvenile females, 79 (12.7%) individuals were adult males, and 361 (58.2%) juvenile males. Based on these data the sex and age ratios in this population were heavily biased towards males (71%), and juveniles (83.8%) (Figure II-2).

The number of birds foraging in the close proximity of the trap (<50m) varied depending on the hour of the day. In the morning the numbers ranged between ca. 10 and 30 birds.

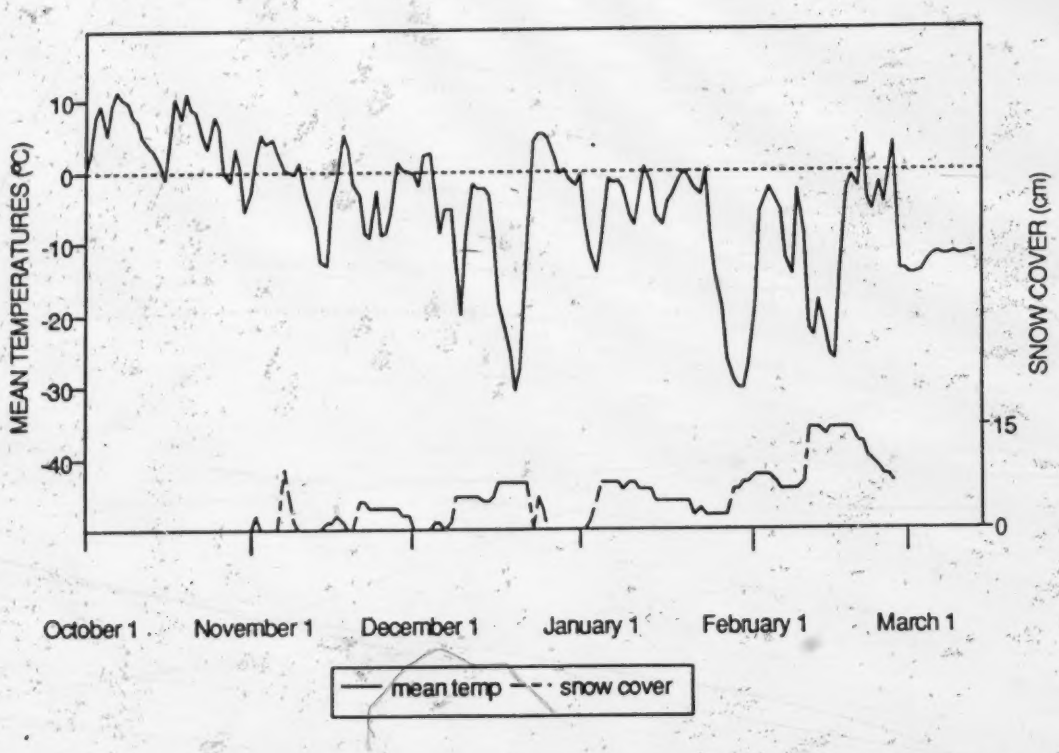

Figure II-1. Temperature and snowfall at the location where mallards were attempting to overwinter on the North Saskatchewan River in the city of Edmonton, Alberta, 1989/1990.

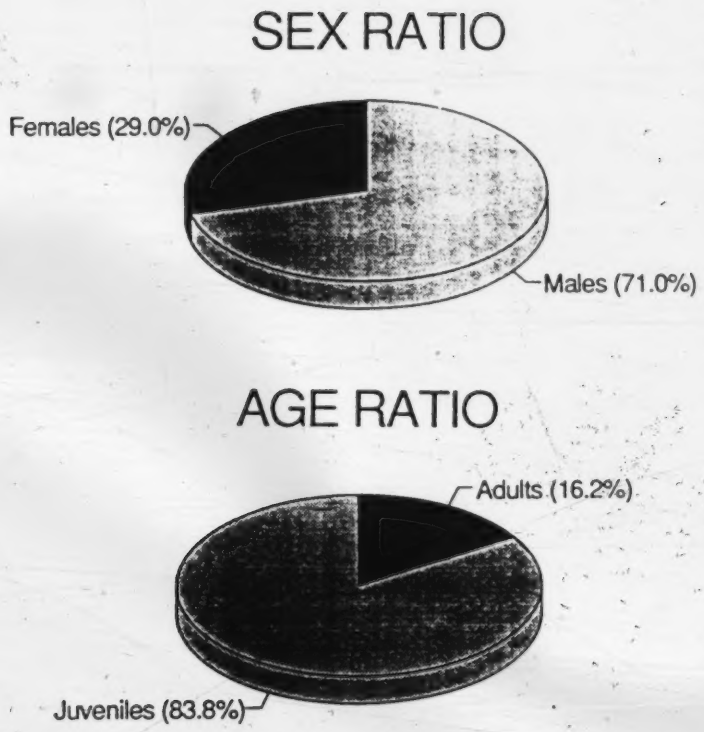

Figure II-2. Sex and age ratio in wild population of mallards overwintering in Edmonton, Alberta, 1989/1990.

The number from morning counts were lower that at other times because the majority of mallards were foraging elsewhere. In the late evening, more mallards were foraging around the trap, and the numbers of individuals ranged from 50 to in excess of 200.

3. Indicators of body condition

The three condition indices (CIW and CIT) and body weight were all highly correlated with total body reserves (lipid and protein) (see chapter III). Among them, CIT showed the highest correlation, explaining 67% of the variation in body reserves in adult females, 92% in adult males, 61% in juvenile females, and 56% in juvenile males. Overall CIT explained only 1-2% more of the variation in juveniles and 5%-6% in adults than body weight alone. Body weight has been used as an indicator of body condition in most wild populations of mallards; it was used here for ease of comparison.

4. Body weight

The body weight of mallards declined continuously from November to March within each sex-age group. But the significant decline in body weight of females and adult males occurred in mid-winter when the daily temperatures dropped below -30°C and continued to decline significantly in juveniles and adult males till the end of the season. Juvenile males lost weight throughout the season with each decline between time blocks being significant (Table II-1).

Adult females and adult males lost 30% and 28% of body weight over the season whereas juvenile females and males lost 23% and 22% of body weight (Table II-1). Overall, adults experienced greater loss of body weight than juveniles (G=24.5; P=0.05), but the difference between the sexes was not significant (G=2.42: P=0.05).

Body weight was significantly correlated with the date of capture. The regression slopes differed (P=0.0001) between age groups and between sexes of adults but not juveniles (P=0.88) suggesting that juvenile males and females were losing weight at a similar but both at a lower rate than in adults (Figure II-3).

Table II-1. Decline in body weight (g; $\bar{x}$±SE; N) of mallards overwintering in Edmonton, Alberta, 1989/1990.

	ADULT				JUVENILE			
TIME[a]	FEMALE		MALE		FEMALE		MALE	
I	1263.0	(1)A[b]	1387.0±41.90	(5)A	1072.4±34.65	(18)A	1215.9±23.54	(52)A
II	1196.3±63.59	(3)A	1320.0±33.88	(20)A	997.7±14.16	(92)A	1120.7±10.47	(211)B
III	969.5±31.20	(17)B	1106.5±18.67	(55)B	898.0±13.43	(84)B	1039.5± 9.23	(296)C
IV	884.8±20.96	(11)B	1003.4±15.74	(49)C	821.1±11.63	(68)C	948.4±11.06	(93)D
%LOSS	30.0		27.7		23.4		22.0	

[a] See text for exact dates

[b] Means in the same column and with the same capital letters are not significantly different ($P>0.05$) for each sex-age group.

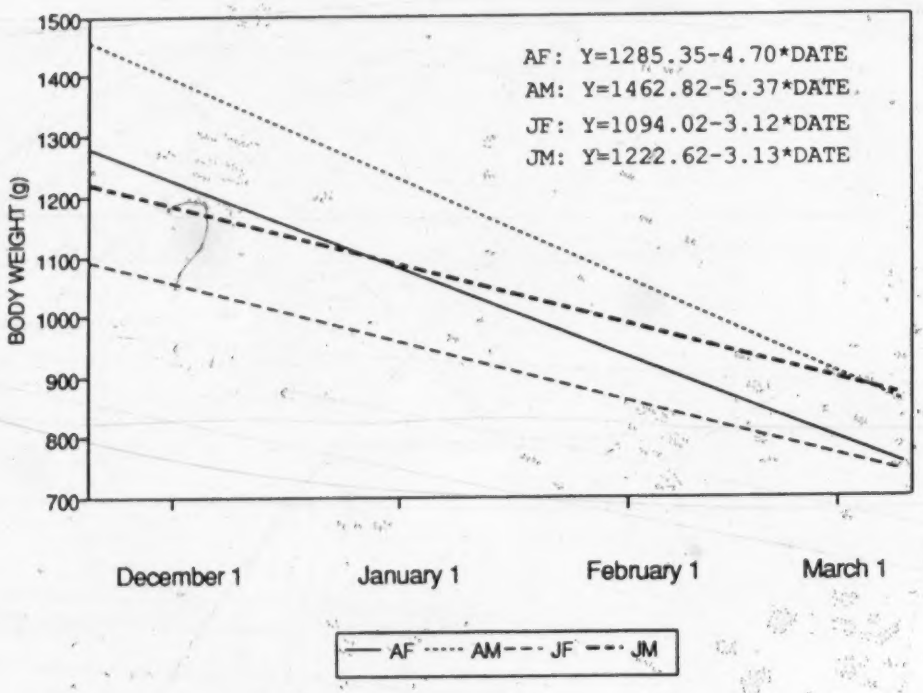

Figure II-3. Relationship between date of weighing and body weight for four sex-age classes of mallards overwintering in Edmonton, Alberta, 1989/1990.

4. Survival

A total of 30 birds was found dead over the season, 21 of which had been banded previously during the winter. Juvenile males made up the majority (63%) in this sample with adult males and juvenile females accounting for 18.6% each, no adult females were recovered.

Among the banded birds found dead, the cause of death was assumed to be starvation (loss of body condition). The mean loss of body weight between November and time of death in February or early March of juvenile males was 39% (N=7) and ranged from 33% to 46%. The mean body weight at death of these birds was 683g, ranging from 504g to 773g. Two adult males were also recovered, each of them having lost 33% and 35% of body weight during the winter season. They weighed 713g and 768g, respectively, at death.

Discussion

1. Changes in body weight and condition.

Seasonal decline in body condition on traditional wintering grounds is typical for wild ducks despite the availability of food. Weights of mallards and other ducks usually increase from August to early November only to fall to their lowest levels in late February and increase again in March just before the spring migration (Folk et al. 1966, Owen and Cook 1977, Whyte and Bolen 1984a). Such weight fluctuations (losses of energy reserves, mainly lipids) have been attributed to a combination of severe weather conditions (Whyte and Bolen 1984b), and the allocation of energy reserves to molt (Heitmeyer 1988), courtship activities and pair bond maintenance (Brodsky and Weatherhead 1985, Pattenden and Boag 1989b).

Mallards in captivity, when exposed to low temperatures and a limited amount of food, showed a decline in body weight but at a rate somewhat in excess of those on an ad libitum diet (Jordan 1953, Pattenden and Boag 1989). Mallards in this study showed a pattern of weight decline similar to that of birds in captivity. They lost weight and condition continuously throughout the winter season with lowest weights just before the spring migration.

The weight loss recorded in food stressed captive birds by Pattenden and Boag (1989b), based on the difference between initial and final weight, averaged 28.4% for adult females and 27.8% for adult males, similar to 30.0% for adult female and 27.7% for adult males recorded in this study. This percentage weight loss, however, says nothing about actual initial and final body weights. When they were considered the percentage weight loss of the wild birds increased. If the initial body weights of wild mallards had been as high as the body weights of the captive birds in November, the percentage weight loss would have been 31.8% for adult females and 32.7% for adult males. These losses are still less than 33-46% loss recorded for males that died, apparently from starvation. Nevertheless, the loss in body weight of live birds over the winter at the latitude of Edmonton would appear to have brought these live mallards to a dangerously low body condition by March.

In March, body weights just before the spring migration of mallards overwintering at the latitude of Edmonton were between 150g and 290g less than those of mallards recorded on traditional wintering grounds (Folk et al. 1966, Owen and Cook 1977, Whyte and Bolen 1984a). They also averaged 86g less for adult males and 80g less for adult females than the body weights of mallards fed a restricted diet in Pattenden and Boag's (1989b) study. Since the restricted diet decreased the captive birds' reproductive potential it suggests that the reproductive potential of wild birds would also be affected, perhaps completely negated, the following spring. Such a conclusion is based on the assumption that the sample of birds trapped was representative of the population as a whole. Therefore, it is essential that the method used to capture birds provides as unbiased (random) sample as possible.

Reinecke and Shaiffer (1988) compared body weight and condition (defined as body weight divided by wing chord length) among ducks captured with unbaited rocket net (control), baited rocket net, baited swim-in trap, and killed by hunters. They found no difference in body weight among collection methods but determined that the body condition of hunter-shot ducks was less than in ducks collected with the other three techniques.

They also suggested that the trapped samples were not biased when a substantial number of birds (more than 20 at a time) was captured. Greenwood et al. (1986) reported that ducks shot by hunters over decoys on a grain stubble weighed less than ducks shot at the their roost area. This suggests that the place of collection plays an important role in eliminating some of the possible biases in obtaining a random sample from a population.

In this study birds were trapped with a baited swim-in trap. During the 58 days of trapping, on 24 occasions the number of ducks captured ranged between 20 and 68 individuals, on 14 it was between 10 and 20 ducks, and on the remaining 20 days it was between 1 and 10 ducks. Moreover, since the trap was set on the shore of the river, the birds which had completely depleted body reserves at the end of the season, and were not able to fly to obtain food elsewhere, were still able to enter the trap and be recorded. The body weights of birds captured only on the grain fields would probably be biased because individuals not capable of flying would have been excluded from the sample.

2. Sex and age ratio.

The sex ratio, biased in favor of males, is a known phenomenon for mallards and other waterfowl wintering in the northern part of their range (Sugden 1974). Pattenden and Boag (1989a) reported a male-biased sex ratio in mallards overwintering on the North Saskatchewan River in Edmonton, Alberta in 1984 and 1985. The proportion of females declined in 1984/1985 from 50% on November 27 to 37% on December 7, after the North Saskatchewan River froze, and continued to decline to 32%. In 1985/1986, during the same period of the winter season, the proportion of females declined from 56 to 37% but, as opposed to the 1984/1985 winter season, the percentage remained unchanged after the freeze-up. They suggested that the male-biased sex ratio was mainly caused by the differential emigration of sexes on the onset of winter with additional sex specific mortality among females occurring only under the harsh winter conditions of 1985. Sugden (1974) reported the ratio between 70% and 79% of males during seven winters in Calgary, Alberta (51°N).

In this study a male-biased sex ratio was also observed. The warm weather conditions at the onset of winter in 1989 eliminated the possibility of sex specific mortality early in the winter and suggested that the differential emigration in late October provide a better explanation for this phenomenon.

The biased age ratio has also been observed in mallards overwintering at northern latitudes. Sugden et al. (1974) reported 63% ratio of juvenile males determined from a sample of 95 males in January. However this ratio varied between winters depending on ambient temperatures. Bellrose (1980) suggested that juveniles hatched late in the season would molt later and may not be prepared physiologically to migrate at the normal time.

A proportion of juvenile birds that remained in Edmonton probably hatched late in the breeding season possible as a result of good habitat conditions on the breeding grounds, high reproductive performance of individuals, and many successful renesting attempts. Several juvenile males (n=8) in the sample handled did not complete their alternate molt until late in December and carried basic plumage on the head, and lower and middle back, they were usually lighter in weight than the fully molted juveniles. They may have been neither physiologically prepared nor had they accumulated enough energy reserves to undertake the fall migration, perhaps, because they hatched late in the breeding season. Later, when these birds became refractory to migratory stimuli and the weather conditions became harsh the birds were forced to cope with whatever conditions prevailed at this latitude. Mild fall weather at northern latitudes could also influence the juveniles' decision to remain north of their traditionally-used wintering ground (Sugden et al. 1974). Furthermore, because the population resided within the city limits, where hunting is prohibited, the juveniles could have found a refuge there from hunters.

Overall the body weights of juveniles from this population in early winter were slightly (4-13%) higher than the weights of juvenile birds from southern wintering grounds (Owen and Cook 1977, Whyte and Bolen 1984a). One possible explanation is that the latter had depleted their energy reserves because they had migrated from breeding areas located further north.

Juvenile males outnumbered juvenile females in this population. Smith and Prince (1977) concluded that males should be able to withstand lower ambient temperatures than females before homeostasis is jeopardized. Structurally larger males have a smaller relative body surface, therefore, they lose heat at a relatively lower rate (Schmidt-Nielsen 1984). Consequently, of the two sexes, one would predict males to outnumber females at the northern parts of their range which is what was recorded in this study and several others (Pattenden and Boag 1989a, Sugden et al. 1974).

4. Survival

Jordan (1953) noted the importance of an ability to withstand temporary and prolonged periods of food shortages by waterfowl in winter. He examined the effects of starvation on wild mallards in captivity. Limited and low energy diet caused the captive birds to reach critical body weights. Adult males which survived the experiment lost 35.7% of initial body weight, whereas, those which did not, lost 47.2% of this initial body weight. The initial body weights of adult males reported by Jordan (1953) were lower than the weights of adult males in this study. Such great loss of body weight would probably not be possible in a wild population because individuals in poor body condition are usually taken easily by predators.

Conroy et al. (1989) reported that juvenile birds with a body weight below the median body weight for the sex group had lower survival potential, possibly because they were less efficient foragers than adults and spent more time on energetically costly activities such as foraging flights. In this study, juveniles (especially males), seem to suffer higher mortality during the winter season than adults. The males were involved in courtship activities, pair formation, maintaining the pair bond, and defending their mates, activities that are not only energy costly but also time consuming leaving less time for foraging. To meet maintenance requirements, males would need greater absolute amounts of food than females, an increasingly difficult requirement as food resources diminished over the winter. Juvenile males have higher levels of energy expenditure than dominant adults because if outcompeted they occupy larger home ranges, and undertake longer foraging flights (Jorde et al. 1984, Whyte et al. 1986).

The overall percentage loss of body weight in this wild population of mallards suggests that they had almost reached the critical level of body weight and condition, beyond which death from starvation was immanent. Since they had almost depleted their energy reserves just before the onset of spring migration, when their body weight should have been rapidly rising, the potential of these birds to be effective members of the spring breeding population seems much in doubt.

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III. Changes in body composition of mallards overwintering in Edmonton, Alberta.

Introduction

Weather conditions on wintering grounds influence physiological conditions (Whyte and Bolen 1984), survival (Conroy et al. 1989, Haramis et al. 1986, Hepp et al. 1986) and reproductive potential of waterfowl (Ankney and McInnes 1978, Drobney 1980, Evans and Smith 1975, Krapu 1981, Pattenden and Boag 1989, Raveling 1979).

Dabbling ducks such as mallards are best adapted to temperatures above 0°C (Prince 1977) but are known to overwinter at northern latitudes where harsh winter conditions prevail (temperatures <0°C). Such birds probably lose body condition in response to low temperatures, which increase the individual's energy demands for thermoregulation, and to winter precipitation (snow), which reduces the availability of food to the individual. The physiological condition of such birds is a function of their body reserves (mainly lipids) relative to their body size (Morton et al. 1990). Typically in waterfowl lipid depots increase from autumn to mid-winter, decline in late winter, and increase again in early spring (Owen and Cook 1977, Reinecke et al. 1982, Whyte and Bolen 1984). These changes in lipid depots correspond closely with fluctuations in body weight (Blem 1976, Miller 1986, Raveling 1979, Reinecke et al. 1982).

Changes in body weight and energy reserves occur in response to changing nutritional and physiological requirements associated with body maintenance (Blem 1976), pairing (Brodsky and Weatherhead 1985), molt (Young and Boag 1982), migration (LaGrande and Dinsmore 1988), and reproduction (Heitmeyer 1988a,b). Harsh climatic conditions, however, could cause additional changes in body weight and lipid levels.

Lipids are the most efficient form of body reserves, providing energy needed to meet the energy demands of the individual.

Proteins are needed mainly for body maintenance, including replacement of body feathers, and as a source of amino-acids for lipid utilization (Blem 1976, Hanson 1962, Heitmeyer 1988b). During extreme thermal stress, however, ducks may use protein as a source of energy (Raveling 1979, Reinecke et al. 1982), but only after both glycogen and lipid reserves are nearly or completely exhausted (Blem 1976, Bonnett and Bolen 1978, Whyte and Bolen 1984). Losses in lipid reserves occur when high energy food is in a short supply but high protein food is available. Such individuals are food stressed and as a consequence they experience loss of body weight through depletion of glycogen accompanied by loss of body water and lipids. During starvation, however, when food is not available, individuals lose body weight not only through a loss of lipid reserves but also through a decrease in protein levels (Evans and Smith 1975).

For several species of waterfowl, evidence exists for a relationship between physiological body condition and overwinter survival. Between age groups, adults are usually heavier, carry more lipid, and are generally in better body condition than juveniles. Thus, adults have a higher probability of survival than juveniles (Conroy 1989, Haramis et al. 1986). Juveniles store less lipids than adults because they engage more frequently than adults in energetically costly activities. They are more mobile, occupy larger home ranges, and could be forced by competitively dominant adults to use less favourable habitats (Jorde et al. 1984, Whyte et al. 1986). Also, adults molt earlier than juveniles and attain higher body weights (Heitmeyer 1987); juveniles seldom complete the prebasic molt while on wintering grounds (Heitmeyer 1988b). Molt inhibits the laying down of lipid depots (Owen and Cook 1977) and birds, molting and migrating, might not be able to accumulate enough energy reserves for completing migration and/or reproduction (Heitmeyer 1988a). Within each sex and age group, heavier individuals have a higher probability of survival than lighter individuals (Conroy 1989, Hepp et al. 1986).

Females, because of their smaller body size and lower ability to conserve heat, have a lower survival potential than males (Schmidt-Nielson 1985, Whyte and Bolen 1984).

But males spend more time courting and swimming and less time feeding than females and as result carry less lipid and have higher energy expenditures (Miller 1986).

Lipid deposition influences not only survival but also the reproductive potential of waterfowl. Birds in better body condition pair earlier and have stronger pair bonds (Brodsky and Watherhead 1985, Hepp et al. 1986, Pattenden and Boag 1989) and are able to allocate energy reserves to egg production, defence of females and nests (LaGrande and Dinsmore 1988, Krapu 1981, Swanson et al. 1985).

The objectives of this study were to (1) document the body composition dynamics of mallards overwintering on the North Saskatchewan River in Edmonton, (2) identify the carcass components associated with changes in body weight and condition, and to (3) relate the changes in body composition to survival and the future reproductive potential of these overwintering mallards.

Study area and methods.

Data on body composition and condition of wild mallards were collected from November 20 to March 15 in 1989/1990 on the North Saskatchewan River in Edmonton, Alberta (53°35'N and 114°30'W). The winter season was subdivided into four blocks of time: early winter (Nov.3-Dec.5), mid-winter Dec.6-Jan.5), late winter (Jan.6-Feb.8), and early spring (Feb.9-Mar.15). Birds were collected during the third and fourth week of each block of time using a swim-in live trap baited with barley. After being removed from the trap, ducks were weighed to the nearest 10g, examined for age determination using the presence or absence of the bursa of Fabricius (Hochbaum 1942) and feather characteristics (Krapu et al. 1979). Tarsus length was measured with a vernier caliper to the nearest 0.01cm and wing length (flattened chord), with a ruler to 0.1cm. These measurements were used to calculate condition indices (CIW=body weight/wing length and CIT=body weight/tarsus length). These (sample of 95 birds) were sacrificed with a lethal dose of chloroform, placed in a labelled plastic bags and frozen for further analysis in the laboratory.

In the laboratory, birds were thawed, weighed to the nearest 0.1g, and dissected. The intestinal tract, ventriculus, gizzard, liver, and gonads were removed from each carcass for further analysis.

These carcasses including plumage were weighed, autoclaved for 6 hours, homogenated in commercial blender, and hand mixed to obtained maximum homogeneity. Duplicate samples of a homogenate (ca. 200g) from each duck were freeze-dried for 5 days to a constant weight. After freeze-drying, one sample from each pair was ground up in a home blender and again duplicate samples were obtained for lipid extraction (ca. 2g each), for protein analysis (ca. 1g each), and for dry matter and ash content analysis (ca. 2g each). Lipid extractions were done in a Goldfish fat extractor using petroleum ether for 4 hours and the extracted fat was weighed after the solvent was evaporated. Protein content was determined using Kjeldahl method. Duplicate samples for dry matter analysis were placed in an oven (110°C), weighed and then ashed in muffle furnace (550°C) to determine the ash content (Appendix 11).

Meteorological data were obtained from Environment Canada at the Municipal Airport in Edmonton.

Data analysis.

1. Weather conditions.

I used Kolmogorov-Smirnov two-sample Test (Sokol and Rohlf 1981) to compare the mean temperatures for the winter season of 1989-1990 with the expected mean temperatures for this period of time based on the long term weather data for the City of Edmonton.

2. Indices of body reserves and condition.

To determine which of these three condition indices (body weight, CIW, or CIT) would predict better the total body reserves of an individual I regressed each of these variables against known quantities of body reserves (lipid and protein) using procedure REG (SAS Institute Inc. 1975).

3. Body weight.

The mean live weights ±SE of collected mallards, from each block of time, and percent loss were also reported and compared, between blocks of time within each sex-age group, using Tukey's studentized test (procedure GLM, SAS Institute Inc. 1975).

4. Body composition.

Percent water, lipid, ash, and protein were regressed against carcass weight to determine which components were responsible for changes in body weights (procedure REG, SAS Institute Inc. 1975). Carcass components (lipid, protein, ash, and moisture) were regressed over time to determine which of them changed significantly in response to winter weather conditions (procedure PROC REG, SAS Institute Inc. 1975). The mean content of carcass components were summarized and percent of loss were calculated for each sex and age group. The losses were considered significant only if the components were correlated with time ($P<0.05$).

Since carcass weight and live weight were highly correlated, I used linear regression equation to predict total lipid, water, ash, and protein levels for live weights of wild mallards trapped, banded, and released during the winter season of 1989/1990 on the North Saskatchewan River in Edmonton (procedure REG, SAS Institute Inc. 1975).

Results.

1. Weather conditions

The winter of 1989/1990 in Edmonton was mild. Except for the month of October ($P>0.05$) the daily mean temperatures were higher than expected for this season ($P=0.01$). During the months of December, January, and February the overwintering birds were exposed to three cold snaps lasting on average 1 week where temperatures ranged between -18°C and -30°C. Snow was accumulated on the ground gradually between December and February, reaching maximum depth of 15 cm on February 15. The total snowfall was lower than expected (Figure II-1 in chapter 2).

2. Indices of body reserves and condition.

The three condition indices (body weight, CIW and CIT) were highly correlated with total body reserves (lipid and protein). Among them, CIT showed the highest correlation, explaining 67% of the variation in body reserves in adult females, 92% in adult males, 61% in juvenile females, and 56% in juvenile males. Overall CIT explained only 1-2% more variation in juveniles and 5-6% in adults than body weight alone. Therefore, the body weight has been used as an indicator of body condition.

3. Body weights

A sample of 95 mallards was collected between November 20, 1989 and March 15, 1990 on the North Saskatchewan River in Edmonton, Alberta. The body weight of mallards declined significantly ($P<0.05$) between November 20 and March 15 within each sex-age class. Adult females and adult males lost between 25 and 36% of body weight over the season, whereas, juveniles lost between 23 and 26% of body weight (Table III-1).

4. Body composition.

Percent lipid content was positively correlated ($p<0.001$) with carcass weight (body weight minus the weight of intestines, gizzard, kidneys, liver, and gonads) for all sex-age groups, whereas percent water content was negatively correlated with carcass weight ($P<0.05$). Percent protein content was not correlated with carcass weight for any sex-age group, as was percent ash (Figure III-1a-d)(Appendix 1)(Table III-2).

Based on these observations, the loss of lipid was the principal body component responsible for the decline in body weight over the winter season. Lipid levels declined significantly between early winter and early spring for all sex-age groups. Protein had also declined but the decline was significant only in males. Ash levels did not change over the season, and water content declined only in juveniles (Appendix 2).

Analysis of means of the carcass composition revealed that between early winter and early spring mallards lost between 65.4 and 92.8% of lipid reserves; these losses ranged from 93.8g in juvenile females, 154.5g in adult female, 162.5 in juvenile males, to 273.4g in adult males, all of which were significant ($P<0.001$). Moreover, among males the protein reserves decreased between 31.0 and 41.3%. In juveniles the decrease of between 15 and 26 % in water content was recorded. Among adults the decline was 22 and 21% but not significant (Table III-3).

Table III-1. Live body weight (g; $\bar{x}$±SE) of mallards collected on the North Saskatchewan River in Edmonton, Alberta.

	Adult		Juvenile	
Time[a]	Female	Male	Female	Male
I	-	1445.0±158.83 (3)*	1158.9±44.85 (8)*	1423.7±78.84 (6)*
II	1157.5 ±56.32 (4)*	1388.5± 49.71 (4)	1036.8±35.27 (12)	1249.7±37.21 (9)
III	990.0 ±71.81 (5)	1227.7± 50.40 (6)	982.0±52.86 (5)	1098.0±54.33 (7)
IV	867.0 ±53.40 (4)*	927.6± 60.89 (6)*	894.0±28.67 (9)*	1048.8±38.22 (6)*
%LOSS	25.1	35.8	22.8	26.3

[a] See text for exact dates

* Means significantly different from each other (P>0.05) within sex-age class .

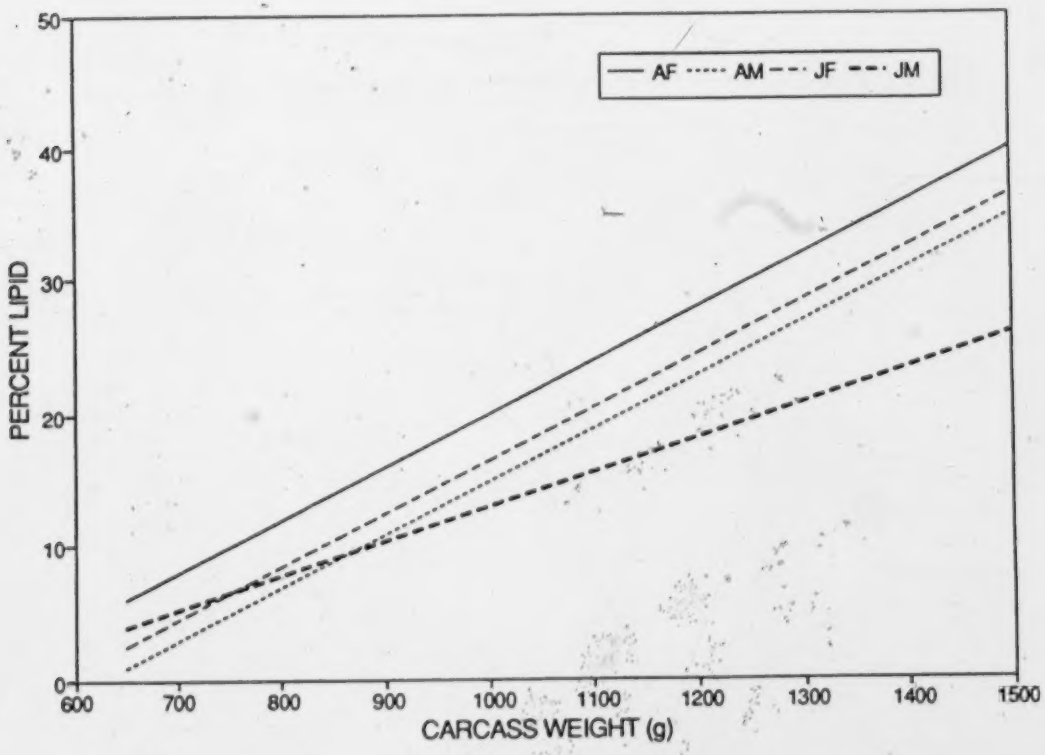

Figure III-1a. Linear regression of percent lipid on carcass weight of mallards overwintering in Edmonton, Alberta, 1989/1990

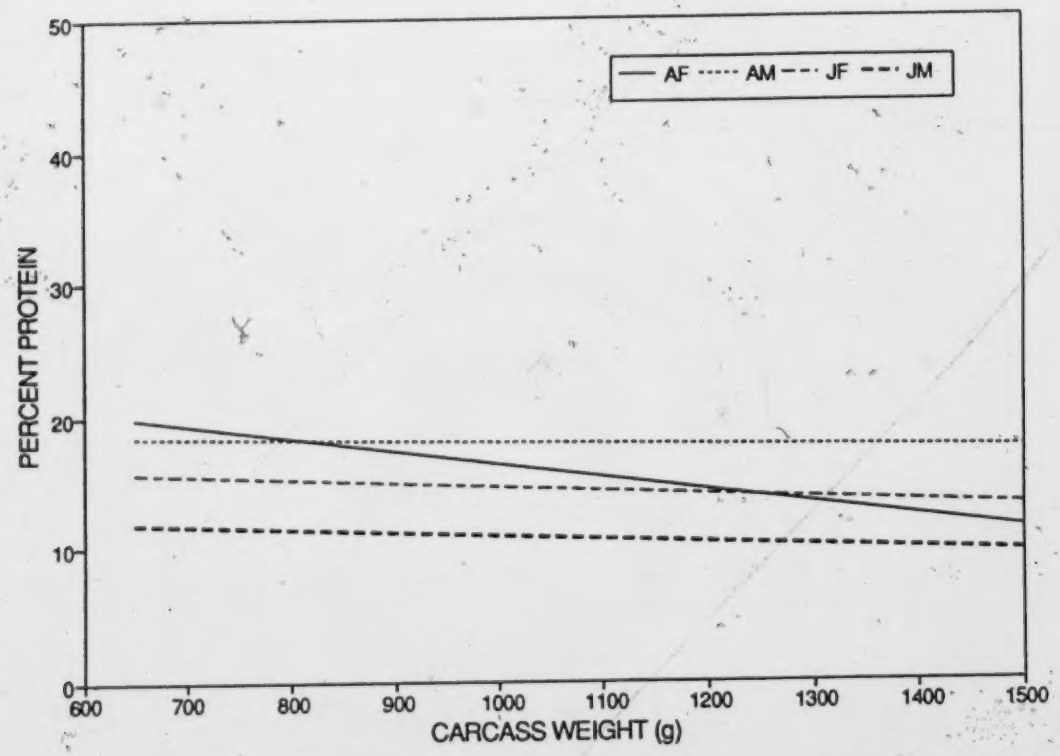

Figure III-1b. Linear regression of percent protein on carcass weight of mallards overwintering in Edmonton, Alberta, 1989/1990.

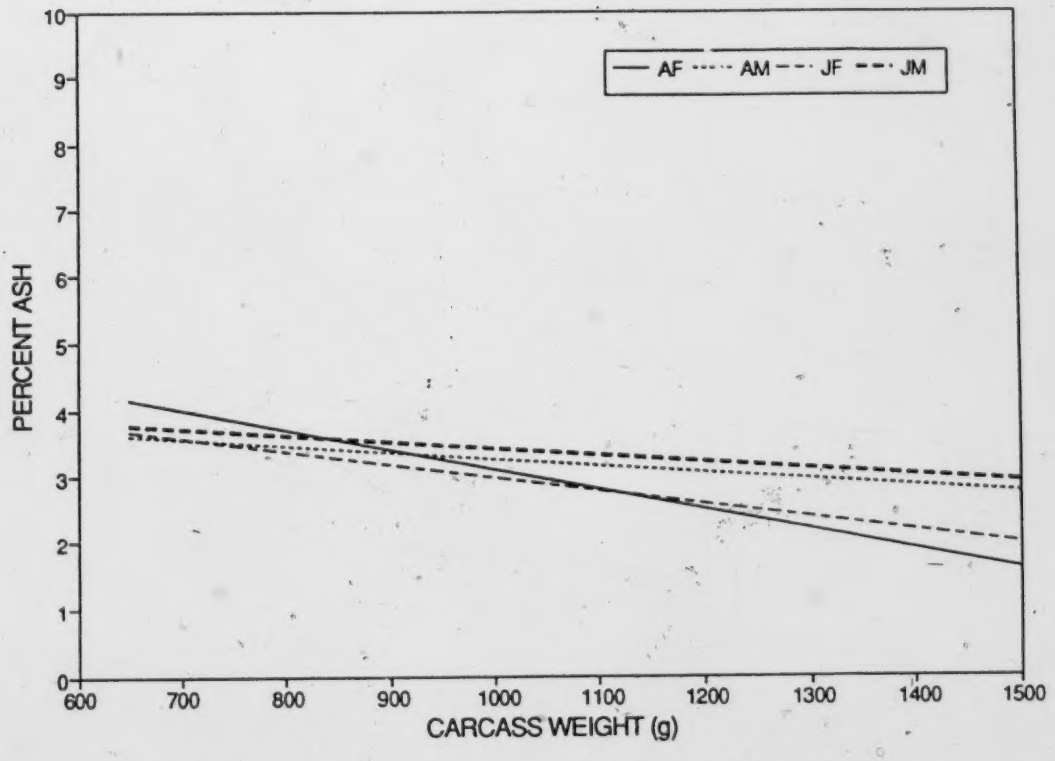

Figure III-1c. Linear regression of percent ash on carcass weight of mallards overwintering in Edmonton, Alberta, 1989/1990.

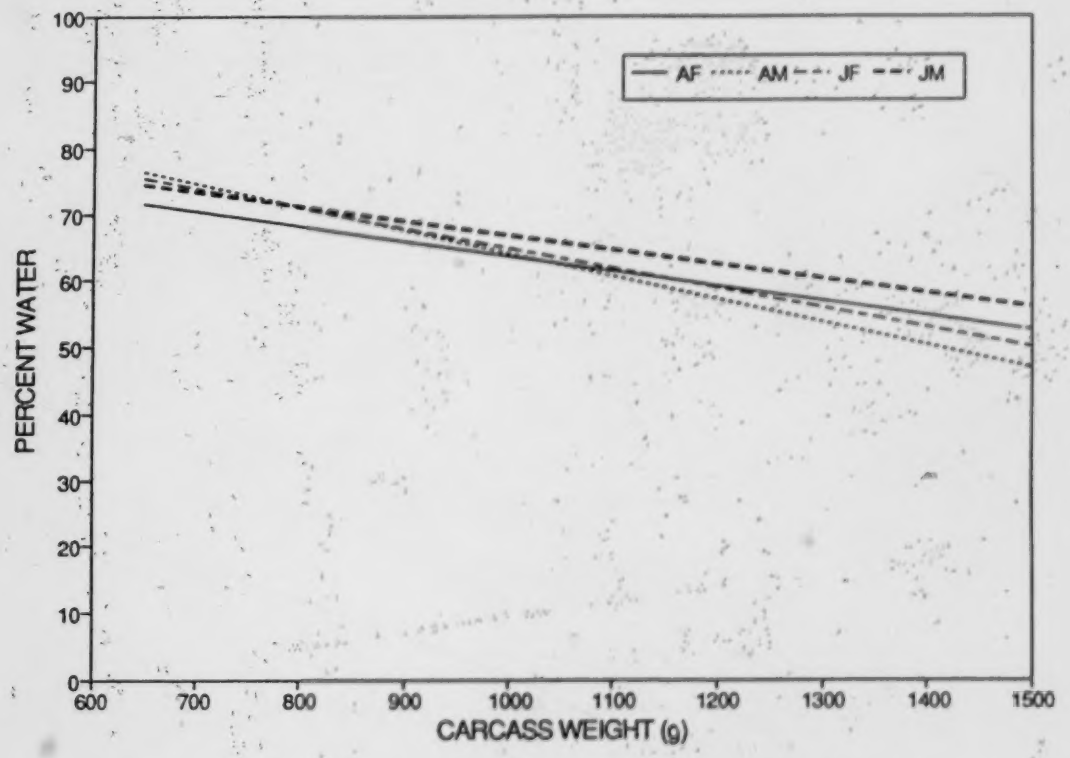

Figure III-1d. Linear regression of percent water on carcass weight of mallards overwintering in Edmonton, Alberta, 1989/1990.

Table III-2. Percent of carcass components of mallards ($\bar{x}$±SE) collected during early winter (I), mid-winter (II), late winter (III), and early spring (IV) of 1989/1990 on the North Saskatchewan River in Edmonton.

TIME*	N	SEXAGE	%FAT	%PROTEIN	%ASH	%WATER	%TOTAL
I	1	AF	–	–	–	–	
II	4		20.08±1.41	14.13±0.49	2.71±0.06	62.45±1.65	99
III	5		11.64±2.81	20.33±1.41	3.92±0.12	63.79±2.82	100
IV	4		6.32±2.53	18.63±2.35	3.95±0.52	69.65±5.26	99
I	8	JF	15.37±3.37	15.53±1.74	3.26±0.33	64.68±4.35	99
II	12		13.09±2.10	13.52±0.91	2.87±0.17	69.21±2.59	99
III	5		11.49±3.46	18.40±1.02	3.23±0.29	67.20±2.70	100
IV	9		7.00±0.97	16.42±1.19	3.54±0.22	71.50±2.11	99
I	4	AM	21.82±5.50	19.25±0.68	3.34±0.37	56.83±3.95	101
II	4		21.71±1.63	17.28±0.26	3.15±0.11	56.52±1.29	99
III	6		12.64±1.58	18.02±0.69	3.53±0.24	64.33±1.53	99
IV	6		2.93±1.06	18.60±2.07	3.73±0.58	73.84±3.03	99
I	6	JM	17.82±2.51	14.28±1.32	2.81±0.63	63.62±2.94	99
II	9		16.88±2.28	17.96±2.06	3.18±0.30	63.15±3.28	101
III	7		8.92±2.28	14.08±0.53	3.13±0.21	72.02±2.27	98
IV	6		6.71±1.18	15.78±1.21	3.50±0.32	71.51±2.89	98

* See text for exact dates.

Table III-3. Carcass composition of mallards (g; $\bar{x}$±SE) collected during early winter (I), mid-winter (II), late winter (III), and early spring (IV) of 1989/1990 on the North Saskatchewan River in Edmonton.

TIME[a]	N	SEXAGE	FAT	PROTEIN	ASH	WATER
I	1	AF	-	-	-	-
II	4		200.65±12.77	141.7± 5.09	27.05±0.41	621.9 ±24.8
III	5		104.70±28.38	168.6±16.11	32.45±2.58	522.9 ±33.8
IV	4		46.70±20.72	128.6±16.37	27.21±3.61	482.2 ±46.9
%LOST[b]			76.72	9.24 NS	0.01 NS	24.46 NS
I	8	JF	144.17±37.22	136.40±16.77	28.29±2.86	548.30±21.49
II	12		119.76±22.14	117.69± 8.31	24.86±1.73	599.93±28.75
III	5		98.96±34.66	145.99±18.28	24.76±1.64	519.21±29.70
IV	9		50.40± 7.47	116.25± 7.95	25.01±1.46	504.94±23.02
%LOST			65.04	14.77 NS	3.28 NS	15.00
I	4	AM	297.70±70.41	233.28±22.93	38.15±1.38	655.83±36.26
II	4		262.26±25.00	207.69± 3.33	37.81±0.79	677.13±23.54
III	6		131.72±16.07	184.98± 8.12	36.82±2.46	655.90±18.25
IV	6		21.33± 7.07	136.84±15.13	28.10±4.18	518.16±44.41
%LOST			92.84	41.34	10.05 NS	20.99 NS
I	6	JM	218.73±37.07	170.25±15.98	33.46±2.77	768.41±61.79
II	9		181.36±28.72	188.03±23.16	33.05±2.99	658.97±44.18
III	7		84.93±26.82	124.03± 7.99	27.32±1.57	629.36±27.03
IV	6		56.27±11.59	128.96±14.97	28.87±3.80	562.94±26.21
%LOST			74.27	24.25	4.59 NS	26.74

[a] See text for exact dates.
[b] Percent weight lost between first and last time period.
NS not significant ($P<0.05$)

Because carcass weight and live weight were highly correlated (Table III-4), I used regression equations describing the relationship between body components and the carcass weight to predict total lipid, protein, water and ash components from live birds caught, banded, and released over the winter season (Appendix 4).

The live birds lost between 22 and 30% of body weight during the winter season. Males lost between 75 and 76% of body lipids and between 24 and 29% of protein. Females lost between 66 and 92% of body lipids and between 18 and 23% of protein (Figure III-2a-d)(Appendix 4).

Discussion.

1. Body weight and energy reserves in wintering mallards.

Mallards on traditional wintering grounds lose body weight and lipid reserves from mid-winter to late winter, gaining weight again in early spring, and thereby increasing lipid reserves to levels well above those in autumn (Folk et al. 1966, Owen and Cook 1977, Whyte and Bolen 1986). This pattern of change occurs even when high energy food is available (Pattenden and Boag 1989, Whyte and Bolen 1986). Fluctuations in body weight and reserves may reflect climatic conditions on wintering grounds (Delnicki and Reinecke 1986, Miller 1986, Raveling 1979, Whyte et al. 1984) and events in the annual cycle that are undertaken during winter, such as molt and pair formation (Heitmeyer 1988a). Lower temperatures which prevail on more northern wintering grounds could increase the energy demands of an individual and thereby affect its body condition even more than that of ducks on southern wintering grounds.

Pattenden and Boag (1989) reported changes in body weight of captive mallards held over winter under ambient conditions at Brooks, Alberta (50°N). Mallards with access to limited amounts of food lost more body weight in response to harsh winter conditions than birds in groups fed on ad libitum diet. The pattern of body weight change over the season in their study differed from that reported on traditional wintering grounds. Except for some fluctuations in early winter which are typical for waterfowl, body weights declined gradually till the early spring, with the magnitude of this decline being greater in groups on a limited diet.

Table III-4. Regression of carcass weight (g) on live weight (x) of mallards overwintering in Edmonton, Alberta, 1989/1990.

Sex-age	Regression equation	r^2	p
Adult female	y=160.52+0.997*x	0.93	0.0001
Juvenile female	y=112.14+1.095*x	0.94	0.0001
Adult male	y=272.09+0.910*x	0.78	0.0001
Juvenile male	y=356.53+0.860*x	0.90	0.0001

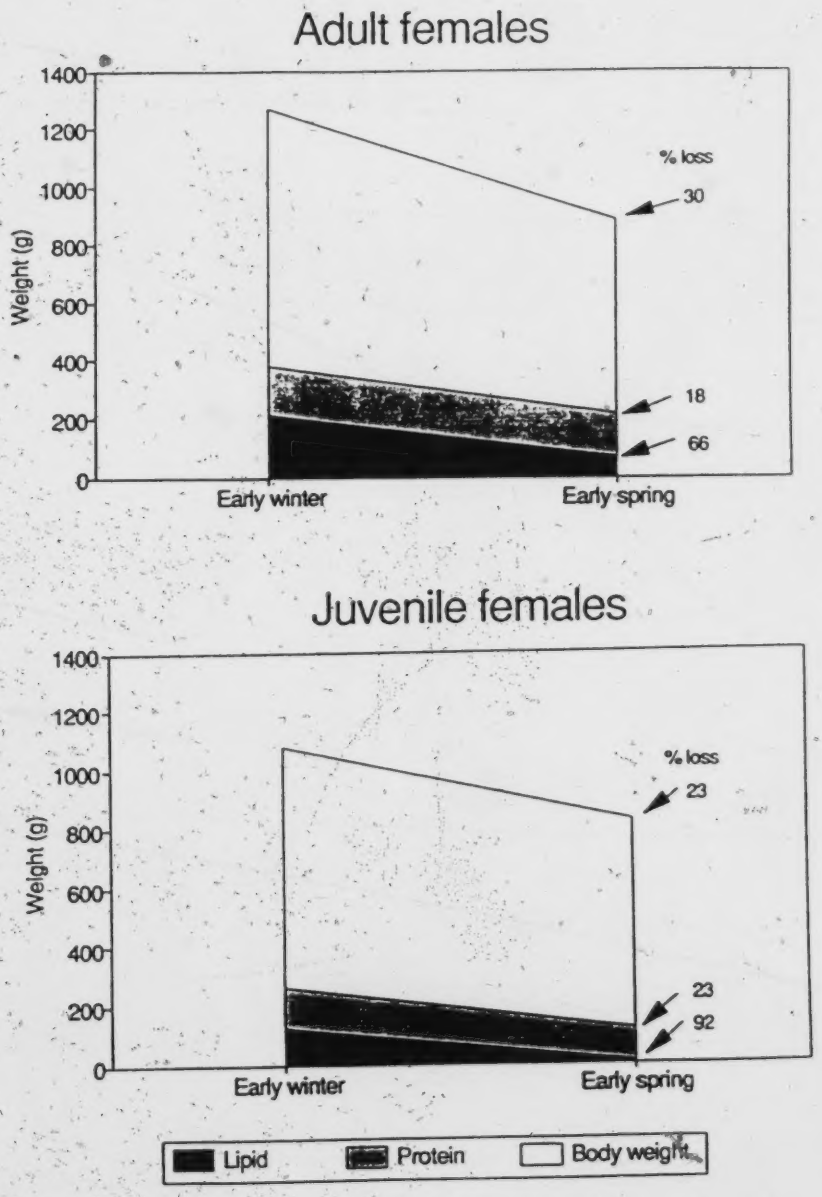

Figure III-2a. Decline of body weight and energy reserves of mallards overwintering in Edmonton, Alberta, 1989/1990.

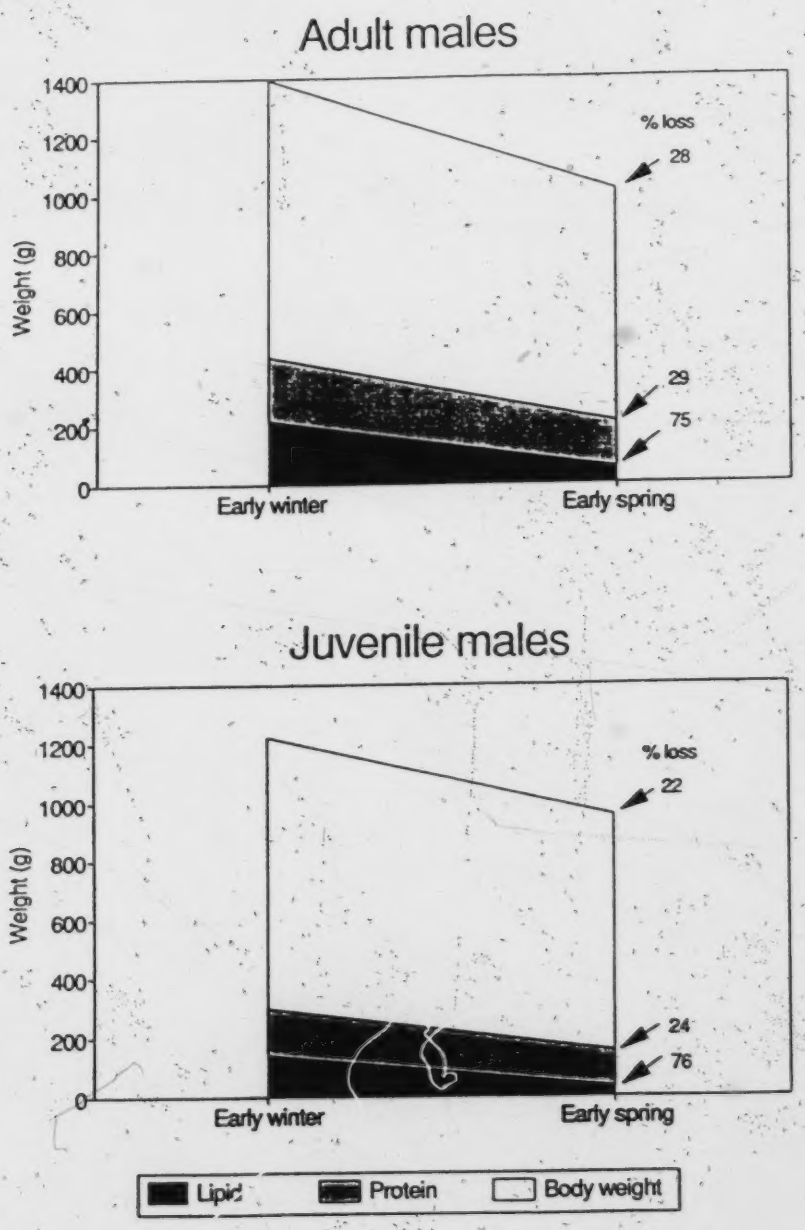

Figure III-2b. Decline of body weight and energy reserves of mallards overwintering in Edmonton, Alberta, 1989/1990.

Pattenden and Boag (1989) assumed that different levels of endogenous energy reserves were responsible for the observed weight changes.

Live body weights of mallards in this study also decreased continuously over the winter season but without evident fluctuations. The autumn body weights were 2-3% lower than those of birds in Pattenden and Boag's study but, except for juvenile females, were 4-27% greater than those reported for mallards in wild population on traditional wintering grounds (Folk et al. 1966, Owen and Cook 1977, Whyte and Bolen 1984). Such differences are to be expected. Birds overwintering further north would avoid the cost of migration imposed on birds moving further south, hence, northern birds could be heavier. The final body weights in early spring in the wild population of mallards from Edmonton were, however, 9-29% below those reported for wild birds on southern wintering grounds (Folk et al. 1966, Owen and Cook 1977, Whyte and Bolen 1984) and also 21-27% below those reported by Pattenden and Boag (1989) for captive birds on a restricted diet.

This suggests that wild mallards overwintering in Edmonton were greatly food stressed and in poor body condition by spring. The continuous decline of body weight as opposed to some early winter fluctuation observed in captive birds (Pattenden and Boag 1989b) was probably caused by additional stresses related to predator avoidance and foraging flights in the wild.

2. Body composition.

The decline in body weights of mallards in this study was caused mainly by loss of lipid content. The extremely high losses of lipid depots by early spring ranged from 66 to 92%. This suggests that the birds were reaching energetic exhaustion by early spring, the critical time when waterfowl are normally increasing their energy reserves in preparation for spring migration and reproductive demands on the breeding grounds (Ankney and MacInnes 1978, Raveling 1979, Krapu 1981, Heitmeyer 1988a).

Females were fatter than males in their respective age classes and between age classes of females, energy reserves of adults were less depleted than those of juveniles during the winter season.

Similar results were reported by Whyte and Bolen (1986). Juveniles store less lipids than adults (this study, Whyte and Bolen 1986) possibly because they engage in activities that are more energetically costly than those of adults, occupying larger home ranges, and undertaking longer foraging flights.

Males consumed from 24 to 29% of their protein reserves. Since protein is known to be utilized after glycogen and lipid reserves are completely exhausted (Blem 1976, Bonnett and Bolen 1978, Whyte and Bolen 1984), it suggests that male mallards overwintering in Edmonton were in very poor body condition. Males from the population in Edmonton were structurally larger than females and adults were structurally larger than juveniles; structure, however, remained constant within each sex-age group since ash content was not significantly correlated with the time of collection. Body water was negatively correlated with body weight, increasing as body lipids declined.

3. The importance of adequate lipid reserves in waterfowl.

a) Molt

Many events in the annual cycle of waterfowl take place on wintering grounds. Activities such as molt, pair formation, and maintenance of pair bonds are energetically costly (Brodsky and Weatherhead 1985). Heitmeyer (1988a), in a study of the relationship between endogenous body reserves, body weights, and molt in wintering mallards reported, that the deposition of lipid reserves precedes pair formation in females. Once paired, females continue to increase their lipid storage and only then initiate the prebasic molt. The protein required for body maintenance was ca. 3.9g/day and the total body protein (for 1050g female mallard) ranged from 160 to 174g, excluding feathers (Heitmeyer 1988b). Females also required 84g of exogenous protein (ca.3g/day), in excess of maintenance requirements, for replacement of body feathers during the prebasic molt. To meet the protein costs during the molt, female mallards also need endogenous lipid reserves to meet daily energy requirements for the extensive foraging needed to obtain the necessary dietary intake of protein-rich invertebrates (Heitmeyer 1988b). Females needed more than 200g of stored lipid before beginning the prebasic molt.

Both sexes in this study were not able to maintain adequate protein levels and protein intake to meet the protein costs of molt.

b). Survival

The build up and maintenance of lipid reserves have survival value in waterfowl (Conroy et al. 1989). Adults have a higher probability of survival than juveniles, and heavier individuals within an age class have a higher probability of survival than lighter individuals (Conroy et al. 1989, Haramis et al. 1986). Data obtained from mallards overwintering in Edmonton support this observation (see chapter II).

b) Reproduction

Low body weights and lipid reserves in food stressed mallards exposed to harsh winter conditions have an impact on initiation of courtship displays in males (Brodsky and Weatherhead 1985, Pattenden and Boag 1989). The permanence of pair bonds also seems to be directly affected by food limitations. Paired females that are subsequently food stressed may actually abandon males (Pattenden and Boag 1989). Delayed pair formation can affect the onset of laying (Hepp and Hair 1984, Brodsky and Weatherhead 1985, Pattenden and Boag 1989). Delayed clutch initiation will result in lower reproductive success during the breeding season in waterfowl (Pattenden and Boag 1989). Furthermore, lipid reserves, obtained before arrival on breeding grounds in wild populations, are needed for egg production, incubation and defense of the female (Krapu 1981).

Thus, analysis of body composition in this study suggests that mallards overwintering in Edmonton were not energetically prepared to meet either the energy demands of spring migration or subsequent reproduction, even if in the immediate vicinity of Edmonton.

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IV. Changes in the visceral morphology of mallards overwintering in Edmonton, Alberta.

Introduction

The availability and use of food sources on wintering grounds influences survival and recruitment of many waterfowl species (Haramis et al. 1986, Heitmeyer and Fredricson 1990). Birds change the nature of the diet both quantitatively and qualitatively during events such as molt, pairing, and energy storage for winter survival, spring migration, and reproduction while still on the wintering grounds (Heitmeyer 1988a,b). When diet quality and quantity changes, visceral morphology of the individual also changes (Fenna and Boag 1974, Kehoe et al. 1988, Paulus 1982, Pendergast and Boag 1972, Whyte and Bolen 1985). Therefore, observing changes in the visceral morphology of birds could provide information on the quality and quantity of food available to waterfowl on the wintering grounds.

Gizzard weight changes in response to diet quality. When birds switched from high fibre diet to high protein diet the gizzard weight declined (Heitmeyer 1988a, Kehoe et al. 1988, Miller 1975, Miller 1986, Whyte and Bolen 1985) along with a decrease in grinding activity (Kehoe et al. 1988, Paulus 1982, Whyte and Bolen 1985).

The losses in gizzard weight could also be attributed to decreased feeding and food intake (Ankney 1977) or to the active metabolisation of endogenous protein as a source of energy, or to the distribution of amino acids for feather production (Morton et al. 1990, Reinecke et al. 1982). Decline in weight of this organ lowers the energetic costs of its maintenance.

The liver is a vital organ in intermediary metabolism as it stores nutrients (glycogen and lipids) after they are absorbed from the gut and releases them as needed (Kehoe et al. 1988). Individuals feeding on high fibre diets have much heavier livers, possibly because of an increase in this organ's metabolic function. The liver weight was observed to increase in response to increased metabolism of protein and lipids with the initiation of prebasic molt (Heitmeyer 1988b).

The kidneys usually increase in volume during periods of intensive foraging, possibly because they need to excrete large quantities of metabolic by-products at such times (Heitmeyer 1988b).

During summer, fall, and winter gonad weight regresses in adult and juvenile mallards. Gradual recrudescence of the gonads of adults and juveniles appears to take place in late midwinter through early spring, with females lagging behind males (Johnson 1961).

The objective of this study was to evaluate the relationship between nutrient reserves, gut morphology, gonadal development, and molt intensity among the sex-age groups of mallards overwintering at northern latitudes.

Study area and methods

Data were collected from sample of mallards trapped and sacrificed between November 20, 1989 and to March 15, 1990 on the North Saskatchewan River in Edmonton, Alberta (53°35'N and 114°30'W). The winter season was subdivided into four blocks of time: early winter (Nov.3-Dec.5), mid winter (Dec.6-Jan.5), late winter (Jan.6-Feb.8), and early spring (Feb.9-Mar.15). Birds were collected during the third and fourth week of each block of time using a swim-in live trap baited with barley. After being removed from the trap the age of the ducks was determined using presence or absence of bursa of Fabricius (Hochbaum 1942) and feather characteristics (Krapu et al. 1979), sacrificed with a lethal dose of chloroform, placed in labelled plastic bags and frozen for further laboratory analysis. In the laboratory birds were thawed, weighed to the nearest 0.1g and dissected. Body weight has been defined as body weight minus crop, gizzard, and esophageal contents. Mass (wet weight) of gizzard, liver, kidneys, and gonads (both testes or ovary) was measured after any attached fat was stripped away.

Then the birds were skinned and the skin was scrapped of excess of fat. The inner skin surface of flat skin was subdivided into six feather tracts (Young and Boag 1981): 1- capital, 2- ventral, 3- anterior ventral and spinal, 4- spinal/scapular, 5- femoral, 6- posterior-caudal.

The molt intensity score was determined by assigning score 1-4 depending on the proportion of area within each feather tract where blood quills were protruding. The system for coding the percent of feather area with blood quills was as follow: 0%=score 0, 0-25% =score 1, 26-50% =score 2, 51-75% =score 3, and 76-100% =score 4. Molt intensity scores from each tract were summed and the total score divided by number of tracts (6) to obtained the final score.

The skins were also examined for external plumage characteristics (Heitmeyer 1987, Young and Boag 1981). The outer skin was divided into 18 areas (Heitmeyer 1987, see also Humprey and Clark 1961) which corresponded closely with the six feather tracts. The number of areas covered by alternate plumage (A), basic plumage (B), or mixture of both (AB) was determined and expressed as a percentage of total (18) areas. A minimum of 11 areas had to be classified before the mean percentage was considered representative.

Data analysis

To examine the effect of the time of collection on organs' weight, grit content, and molt intensity I performed an analysis of variance (ANOVA) based on type III sum of squares (procedure GLM, SAS Institute Inc. 1975). I also used Tukey's studentized range test to separate differences in mean organ weights, grit content, and molt characteristics among collection periods for each sex-age group (Multiple comparison procedure GLM, SAS Institute Inc. 1975). The results were considered nonsignificant if the P value exceeded 0.05.

Results

The results of analysis of variance showed, that the time of collection affected only the weight of liver in juvenile females (F=3.19, P=0.0385) and the grit content in adult males (F=5.15, P=0.0145). The analysis of means among collection periods confirmed the above findings.

The weight of kidneys for each sex-age category of mallards wintering on the North Saskatchewan River in Edmonton remained stable (P>0.05) between early winter and early spring (Figure IV-1, Appendix 5). The same was true of the gonads and gizzards (Figure IV-2, Appendix 6 and Figure IV-3, Appendix 7).

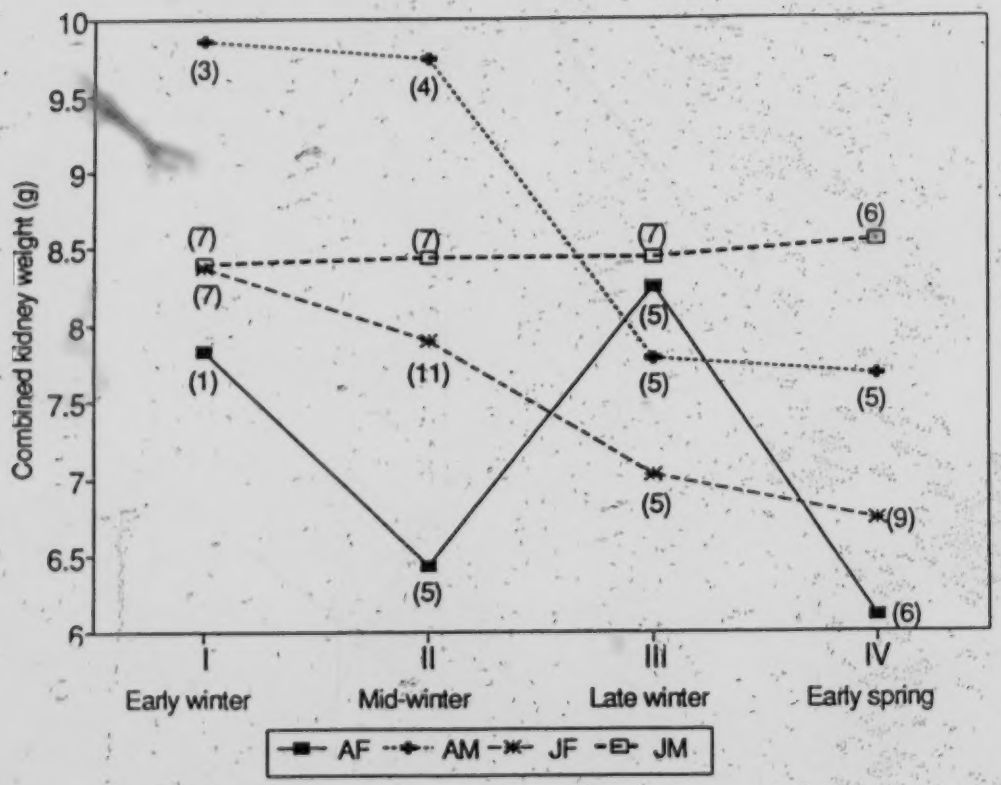
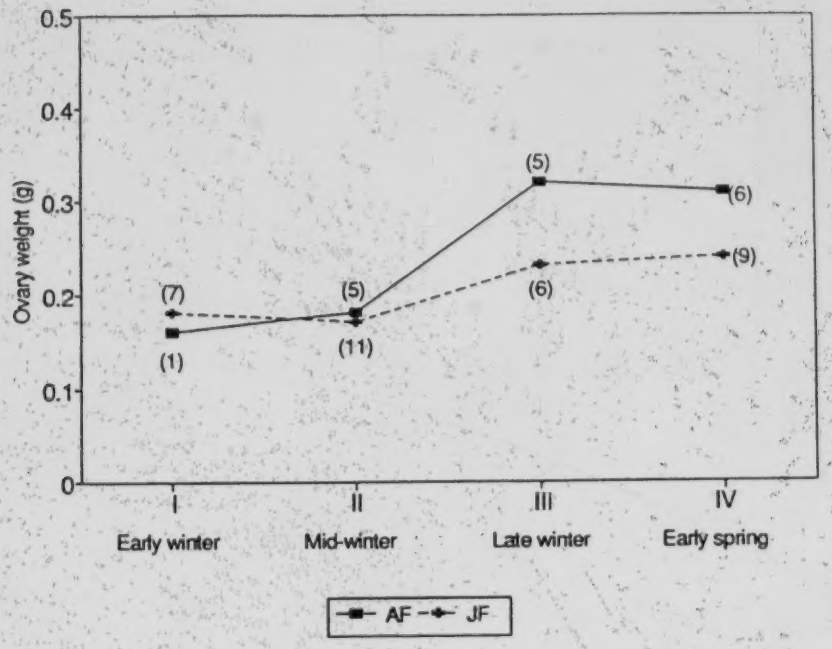


Figure IV-1. Combined wet weights of two kidneys of mallards collected in Edmonton, Alberta, between early winter,1989 and early spring, 1990.



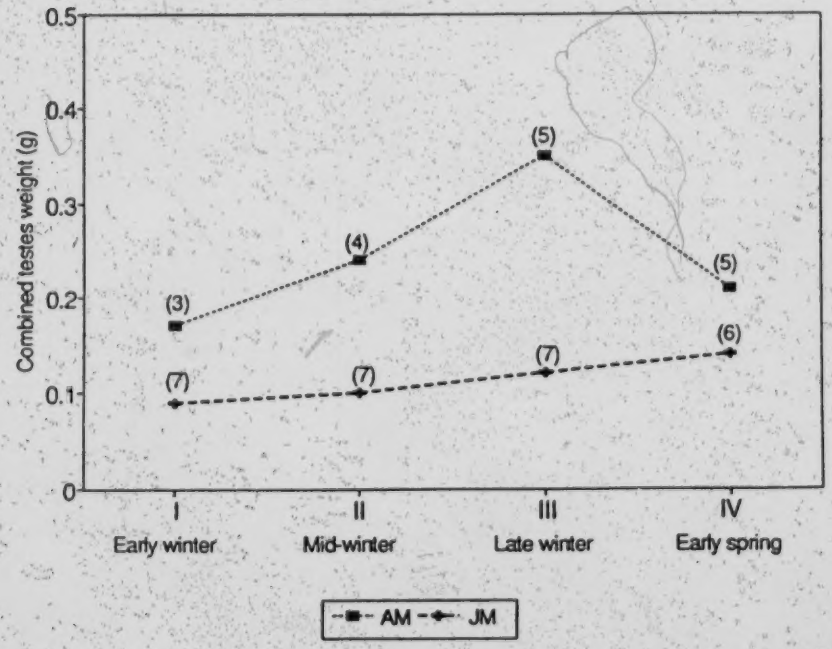


Figure IV-2. Wet weights of gonads of mallards collected in Edmonton, Alberta, between early winter,1989 and early spring, 1990.

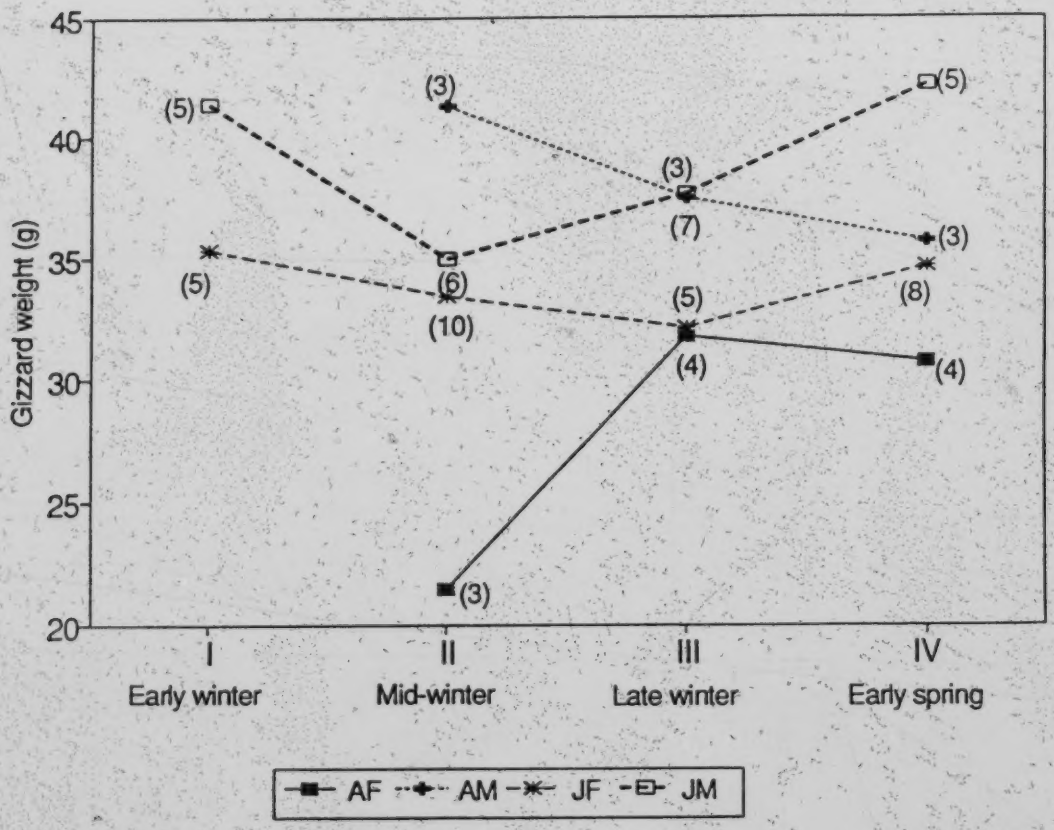


Figure IV-3. Gizzard wet weights of mallards collected in Edmonton, Alberta, between early winter, 1989 and early spring, 1990.

Adult males showed an increase in grit content of gizzard in early spring, suggesting an increase in grinding activities of the gizzard (Figure IV-4, Appendix 8). This could have been a result of improved foraging opportunities once the snow began to melt and foods high in fibre and energy had become available again. Juvenile males and adult females also showed an increase in this variable but the change was not significant ($P>0.05$). It is possible that gizzard weights did not change with changing grinding activities because of a lack of response time.

The wet weights of livers did not change significantly over the period sampled (Figure IV-5, Appendix 9). Nevertheless, the mean weights of livers fluctuated during the winter season with a trend towards lighter weights in spring than early winter. Only when sample sizes were larger (juvenile females) was this trend significant ($P<0.05$).

Most mallards from this overwintering population were not molting intensively over this period (Figure IV-6, Appendix 10). The maximum mean scores were recorded for juvenile females in early and mid-winter. Adult males had completed the molt with alternate plumage by early winter and adult females, by mid-winter (Figure IV-7a,b). Apart from adult females, the molt intensity score showed a decrease from early to mid-winter and then remained unchanged. No new developing contour feathers were observed in adult males. It is difficult to interpret changes in plumage and molt intensity in adult females because of the small sample size, but four individuals analyzed from early spring were mainly in alternate plumage. The presence of some basic feathers may suggest these adult females had already initiated prebasic molt or were still acquiring alternate plumage.

Juvenile birds were molting almost continuously during this period (Figure IV-7c,d). However, there were some differences between the sexes. Juvenile males had almost completed the molt into alternate plumage by early spring whereas juvenile females, despite the highest molt intensity scores, were still acquiring alternate plumage in early spring.

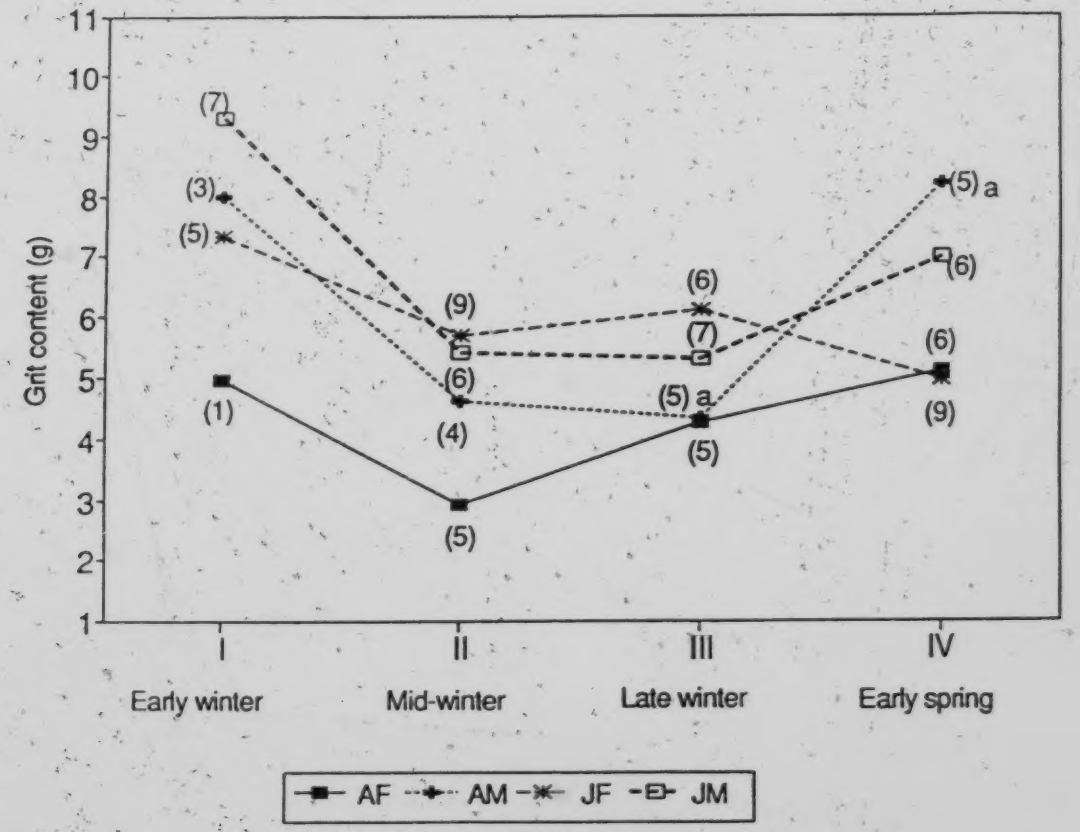


Figure IV-4. Grit content of mallards collected in Edmonton, Alberta, between early winter, 1989 and early spring, 1990.

a Means significantly different ($P<0.05$) within sex-age class.

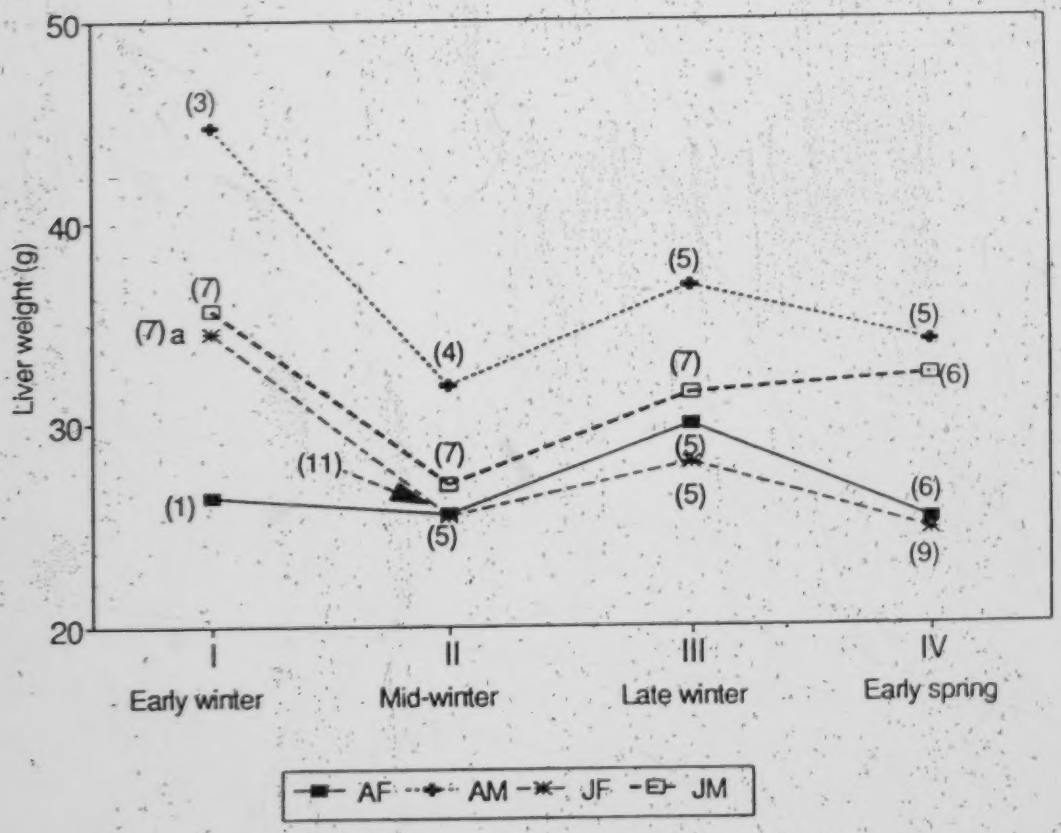


Figure IV-5. Liver wet weights of mallards collected in Edmonton, Alberta, between early winter, 1989 and early spring, 1990.

a Mean significant different ($P<0.05$) from other means within sex-age class.

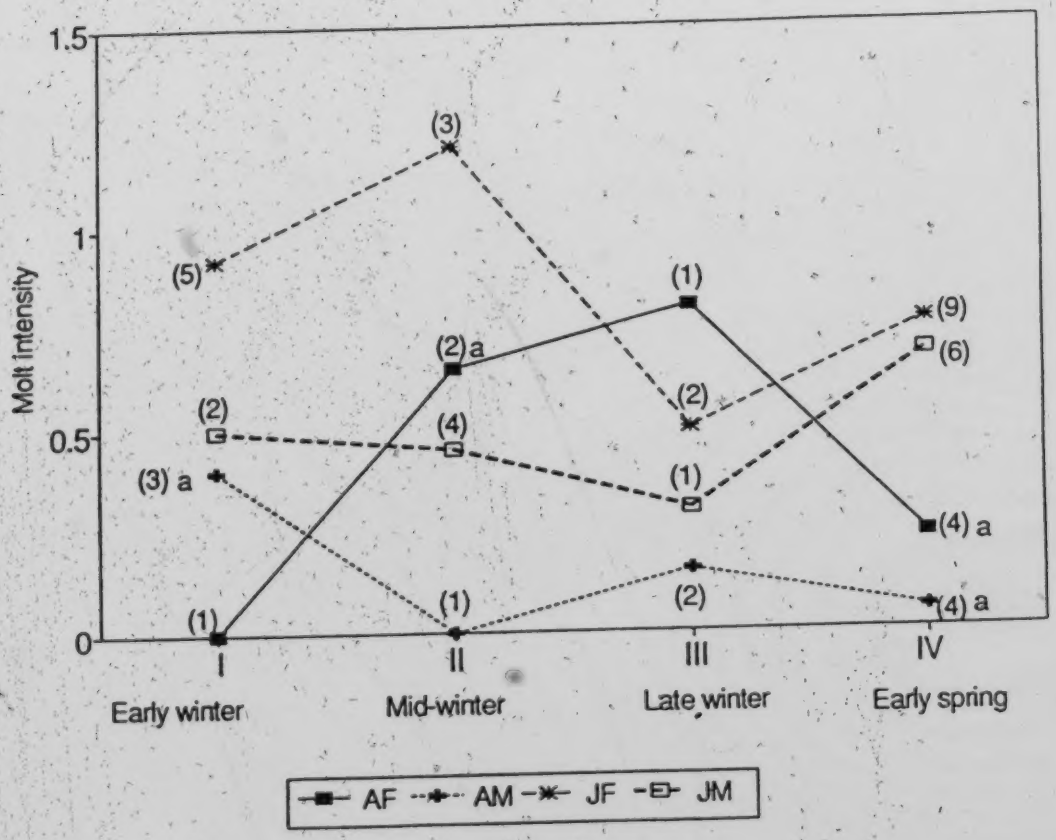


Figure IV-6. Molt intensity score of mallards collected in Edmonton, Alberta, between early winter, 1989 and early spring, 1990.

a Means significantly different ($P<0.05$) within sex-age class.

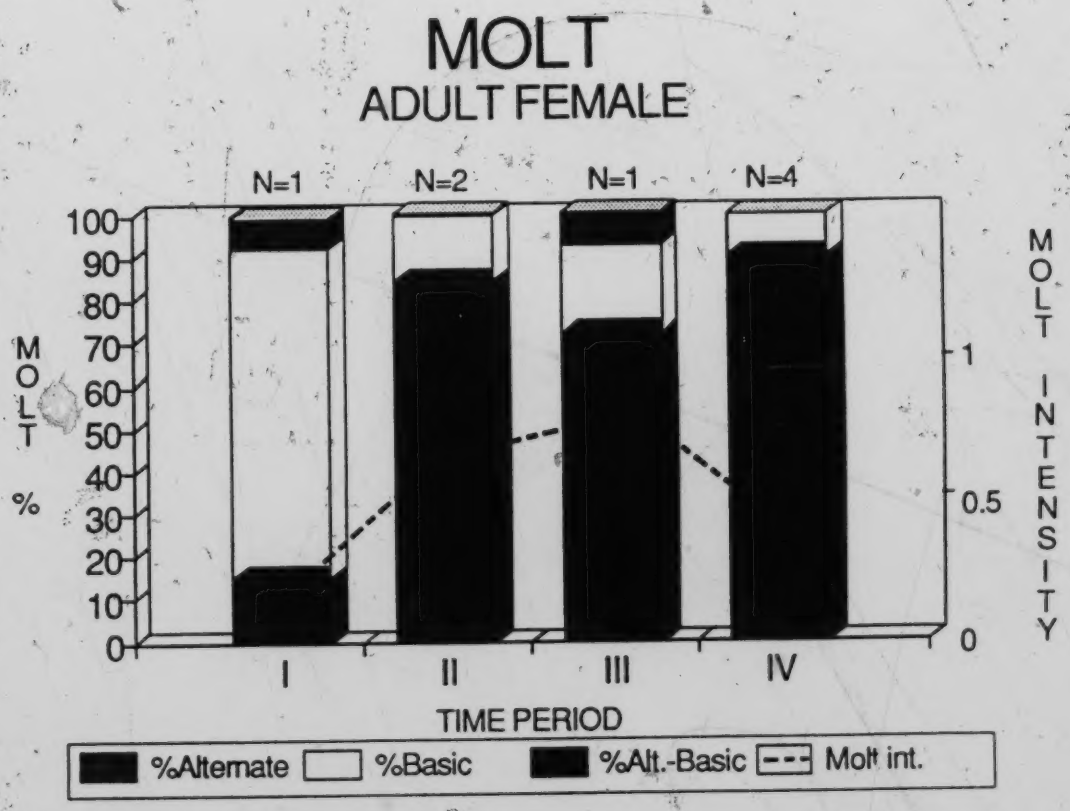


Figure IV-7a. Changes in molt and molt intensity of mallards wintering in Edmonton, Alberta, 1989/1990.

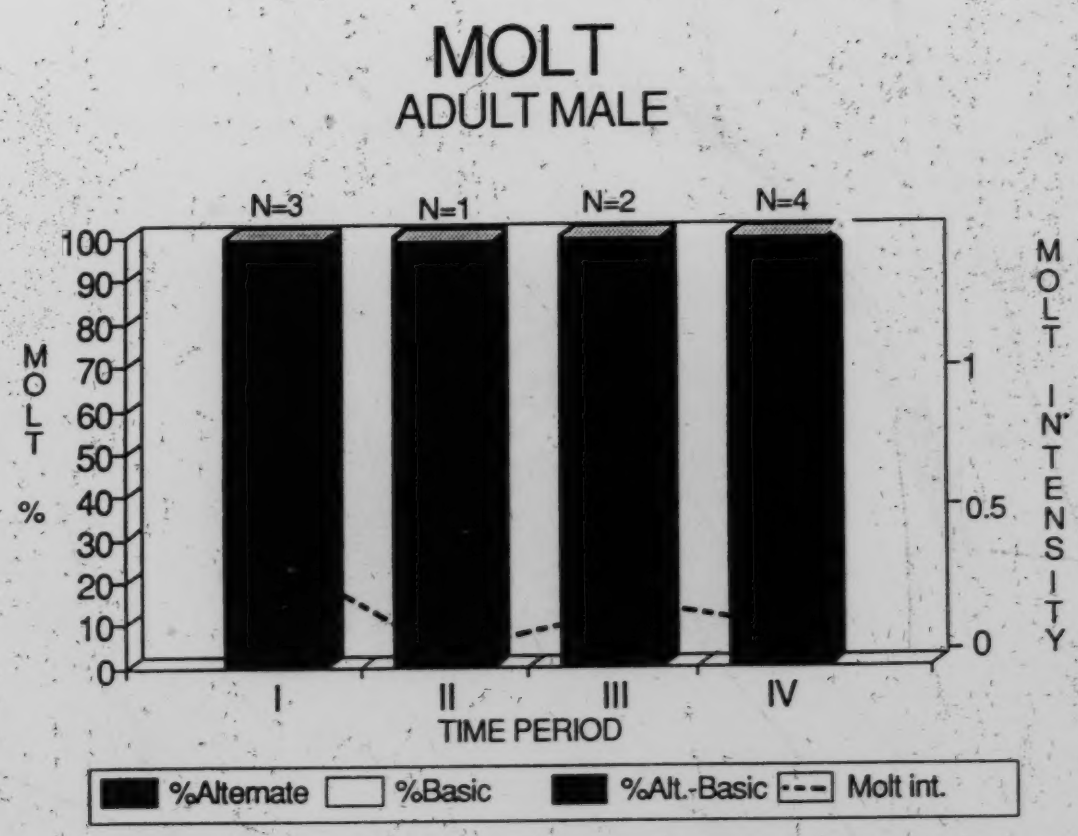


Figure IV-7b. Changes in molt and molt intensity of mallards wintering in Edmonton, Alberta, 1989/1990

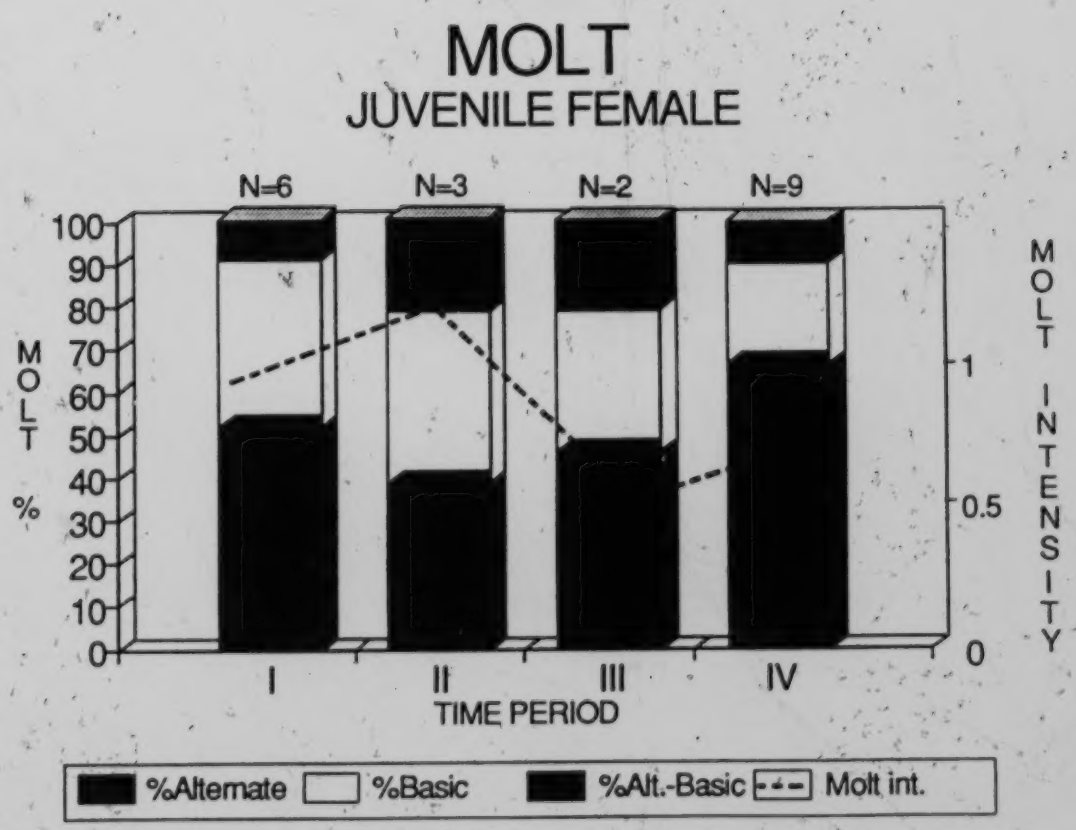


Figure IV-16. Changes in molt and molt intensity of mallards wintering in Edmonton, Alberta, 1989/1990.

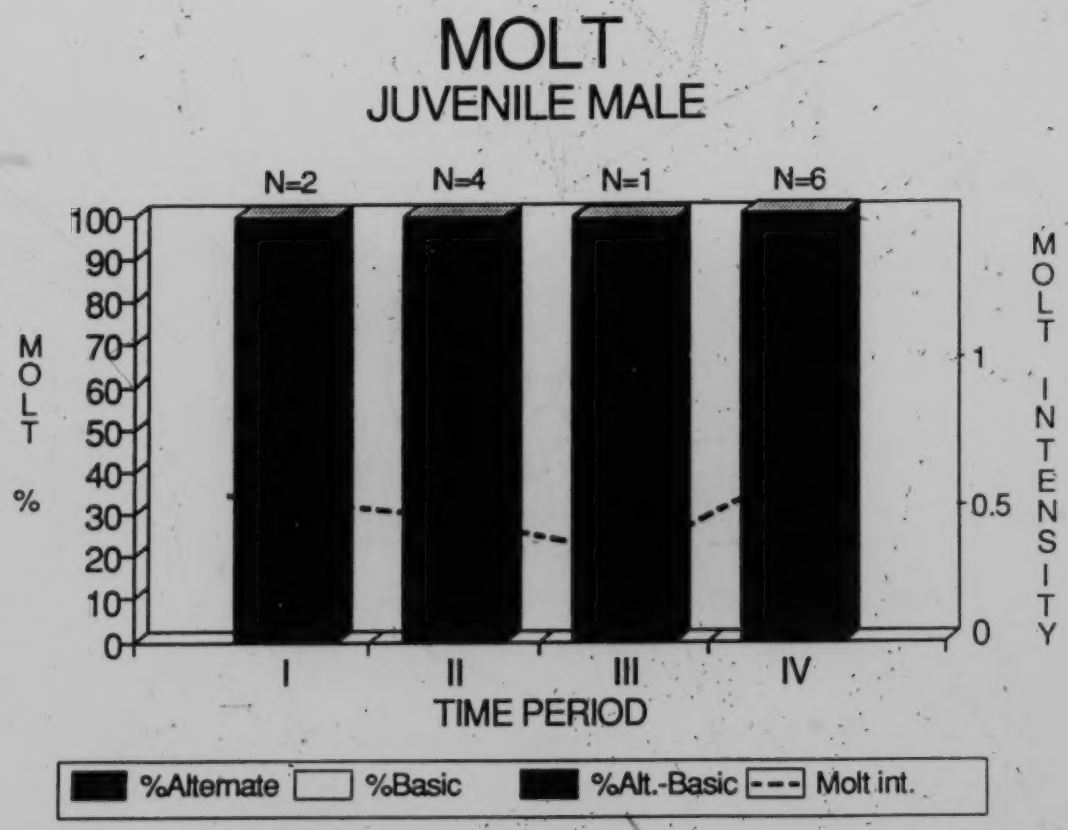


Figure IV-7d. Changes in molt and molt intensity of mallards wintering in Edmonton, 1989/1990.

Discussion

Mallards overwintering on the North Saskatchewan River in Edmonton were in poor body condition and had greatly depleted energy reserves (see chapter III). They were exposed to low temperatures and had limited access to food of adequate quantity and quality.

During the winter season mallards are usually involved in many activities such as foraging, flying, swimming, walking, thermoregulation, pair formation, molting, and the developing lipid reserves for insulation, migration, and reproduction. Many of these activities impose very specific nutrient requirements on the individual. Molt requires adequate protein intake from an appropriate source. The results of this study suggest that protein was not available in appropriate amounts.

The overwintering birds may also change their food intake. Birds were observed to increase food intake, consuming larger volumes of food, in response to low temperatures, which increase costs of thermoregulation, or in response to a low energy diet to compensate for low caloric content (Paulus 1982, Perry et al. 1986).

All these circumstances influence the individual's overall body condition and may cause changes in visceral morphology which could be considered a plastic response to nutrient availability and nutrient requirements (Kehoe et al. 1988). Also it could be a strategy to lower maintenance costs by reducing the size of organs.

Mallards on the North Saskatchewan River had organs generally smaller or comparable to those of birds from southern wintering grounds. The gizzard weights reported for mallards in Texas, where they were not food stressed, were similar to those recorded in Edmonton (adult male: 38.0g versus 35.7g, adult female: 34.3 versus 30.7g, juvenile female: 36.1g versus 34.6, and juvenile males: 42.2g versus 36.8g (Whyte and Bolen 1985, this study). The generally lower gizzard weights of birds overwintering at northern latitudes may reflect the small volume of food processed per unit time (Fenna and Boag 1974), either because birds were not foraging to conserve energy or because food availability was very low resulting in low consumption rates.

In contrast to the gizzards of mallards in Texas, which decreased in weight throughout the winter season, those of mallards collected in Edmonton remained unchanged over the winter season. Texas birds were not food stressed and generally in good body condition but the diet they consumed was low in fibre and therefore the birds were not obliged to consume large quantities (Whyte and Bolen 1985). The gizzard weights of mallards from Edmonton population may have remained unchanged because, although food stressed, they were unable to increase food intake either with declining quality or declining availability.

Apart from adult males, the liver weights reported for mallards in Texas (Whyte and Bolen 1985) were generally greater than those of Edmonton in early spring(33.2 versus 34.0g for adult male , 31.0 versus 27.2g for adult female, 35.6 versus 32.3g for juvenile male, and 31.6 versus 24.7g for juvenile female. The Edmonton birds had greatly depleted energy reserves (see Chapter III) which probably was reflected in lower amounts of stored glycogen and lipids in liver than for birds from more southern wintering sites. The fact that juvenile females had relatively the lowest liver weights (78% of Texas birds) suggest that they may have been the sex-age class most vulnerable to starvation. They also have the lowest status in a dominance hierarchy (Pattenden and Boag 1989b) and hence the least access to resources in short supply. The low liver weights in juvenile females may be reflected in the apparent postponing of the acquisition of alternate plumage until spring.

The mean weights of ovaries from mallards collected in Edmonton were also lower than those reported for birds wintering on more southern wintering grounds. Johnson (1961) reported that the ovaries of adult females weighed 2.0g in early spring and of juvenile females 2.2g; whereas in Edmonton they weighed 0.3g and 0.2g, respectively. The mean weight of both testes from individual males collected in Edmonton in early spring was also less (adult males: 0.2g and juvenile males: 0.1g) than the weight of testes (7.8g) reported by Johnson (1961) for males from southeastern Washington.

Based on the above observations, mallards overwintering at northern latitudes appear to be unable to compensate for either low quality of food by switching diet, or low quantity by consuming more food per unit time. This led to low weights of the gastro-intestinal system, a declining body condition, and at least in juveniles, delayed molt. All this suggests that the reproductive potential of such birds would be lower than that of normal migrant the following spring.

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V. Concluding discussion

This study was undertaken to address the possibility that mallards wintering north of their normal range were entering an ecological trap which had the potential to negatively affect both their reproductive potential and survival. To investigate the possibility, I examined the effects of winter conditions on body weight and survival of mallards (*Anas platyrhynchos*), overwintering on the North Saskatchewan River in Edmonton, Alberta (53N°), by recording changes in body weight of these birds over the period from November 1989 to March 1990. I documented changes in their body composition to determine which body components were responsible for the observed changes in body weight. I examined visceral morphology of these overwintering mallards to assess the quality and quantity of nutrients available to these birds under harsh winter conditions. I compared the size of gonads of mallards from the Edmonton population to that of birds from traditional southern wintering grounds to assess their sexual maturity in early spring. I also monitored the intensity of molt and patterns of change in plumage to determine if these birds were able to initiate prebasic molt before spring migration.

Mallards attempting to overwinter in Edmonton latitudes entered the season weighing 4-27% more than mallards which had migrated to southern wintering grounds (Folk et al. 1966, Owen and Cook 1977, Whyte and Bolen 1984). This difference may be explained by the costs of migration imposed on these birds which took part in the traditional autumn migration. Despite the higher initial weight, mallards overwintering at the latitude of Edmonton lost 23-30% of body weight between November 20 and March 15. Their final weights in early spring were 9-29% below those reported from wild populations on southern wintering grounds (Folk et al. 1966, Owen and Cook 1977, Whyte and Bolen 1984).

Live body weight of mallards in this study decreased continuously over the winter season without evident fluctuations. Such a pattern of weight change differs from that observed on traditional wintering grounds where body weight tends to decline in January and increase again in late February and March, just before spring migration.

This suggest that the mallards leave southern wintering grounds in good body condition with large accumulated energy reserves (Folk et al. 1966, Owen and Cook 1977, Whyte and Bolen 1984, Whyte et al. 1986). By contrast, birds overwintering at northern latitudes, where they were exposed to much harsher winter conditions than the former, appeared to be in a dangerously poor body condition.

The decline in body weight in this study was caused mainly by a loss of lipid content. The loss of lipids between November 20 and March 15 ranged from 66-92%. This suggests that some birds were reaching energetic exhaustion before spring migration.

Mallards overwintering on the North Saskatchewan River had organs generally smaller or comparable to those of birds from southern wintering grounds (Whyte and Bolen 1985); they remained stable over the season. The size of the gonads in early spring was also small in comparision to birds wintering further south (Johnson 1961). The molt appeared to delayed, at least in juveniles.

One very interesting feature of this population was the sex and age ratio. The sex ratio in this population of mallards was biased in favor of males. Such bias has also been reported for other populations of mallards wintering in the northern part of their range (Sugden et al. 1974, Pattenden and Boag 1989). This observed bias was probably caused by differential emigration of sexes in autumn as suggested by Pattenden and Boag (1989).

A biased age ratio has also been observed in mallards overwintering at the northern latitudes (Sugden et al. 1974, this study). There are at least three possible explanations of this phenomenon. As Bellrose (1980) suggested, juveniles hatched late in the season would molt later and may not be prepared physiologically to migrate at the normal time. According to Sugden et al. (1974), mild fall temperatures at northern sites influence juveniles to remain north of traditionally-used wintering grounds. In the case of the Edmonton birds, and those studied by Sugden et al. 1974), juveniles could have found a refuge from hunters by residing within the city limits where hunting is prohibited.

A proportion of juvenile mallards that overwintered in Edmonton probably hatched late in the breeding season. This suggestion is based on an observed delay in the molt, and presence of the bursa of Fabricius as late as January.

The mild weather conditions in fall in Edmonton, and the release from hunting pressure could also have encouraged these immature juveniles to stay.

The number of juveniles in the population studied could also be indirectly influenced by conditions on the breeding grounds and breeding success that year. In summer of 1988 Alberta experienced severe drought which affected the breeding success of mallards and possibly other waterfowl. The number of juveniles banded in August of 1988 declined by 41% compared to the summer of 1987, when the wetland conditions appeared to be normal, and increased again by 35% in summer of 1989 (Paul Pryor, Canadian Wildlife Service, personal communication). Good habitat conditions on the breeding ground allows for greater number of renesting attempts which could be measured by the number of flightless juvenile birds captured, and banded in August. In 1988 (the dry summer) flightless birds accounted for 5% of the trapped sample of juveniles, whereas, in summer of 1989 the number of flightless juveniles increased to 9%. These data suggest that a large number of late hatched juvenile birds, from successful renesting attempts, could have contributed to the overwintering population in Edmonton. Also the percentage of juvenile males from the summer trapped sample corresponds closely with the observed sex ratio in the juvenile group recorded from the winter population. This could suggest that the observed sex and age ratios were influenced by reproductive success of mallards on breeding grounds that year. This could also support what Bellrose (1980) suggested in regards to late hatched juveniles and their physiological state before fall migration.

Based on results from this study it could be concluded that mallards overwintering at northern latitudes had greatly depleted energy reserves before the onset of spring migration, when their body weight should have been rising rapidly. The lack of energy reserves, necessary for migration and reproduction, would lower the birds' reproductive potential.

The analysis of visceral morphology of these overwintering birds suggested that both the quality and/or quantity of food were not available in sufficient amount, and that the birds were not able to compensate for either low quality of food by switching diet, or low quantity by consuming more food per unit time.

The population was "young" because of the large proportion of juveniles present, which suggests that, despite surviving over the winter, such birds would probably contribute little to the mallard population during the following breeding season.

The results from this study allow better understanding of waterfowl winter physioecology and underline the importance of winter season to waterfowl future reproductive success. They also provide an excellent baseline to which data on waterfowl body condition from traditional wintering grounds could be compared to.

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Appendix 1. Regression of body component (%) on carcass weight (x) of mallards collected on the North Saskatchewan River in Edmonton, Alberta, 1989/1990.

%	SEX-AGE	Regression equation	r^2	P
lipid	FA	y=-20.02+0.040*x	0.76	0.0001
protein		y= 26.32-0.010*x	0.11	0.1317
ash		y= 6.08-0.003*x	0.35	0.1450
water		y= 85.77-0.022*x	0.23	0.0460
lipid	FJ	y=-23.56+0.040*x	0.60	0.0001
protein		y= 17.53-0.003*x	-0.02	0.6096
ash		y= 4.98-0.002*x	0.14	0.0172
water		y= 95.06-0.030*x	0.25	0.0017
lipid	MA	y=-25.17+0.040*x	0.87	0.0001
protein		y= 18.95-0.001*x	-0.06	0.8091
ash		y= 4.25-0.001*x	-0.01	0.3834
water		y= 99.29-0.035*x	0.79	0.0001
lipid	MJ	y=-13.05+0.026*x	0.56	0.0001
protein		y= 13.75+0.003*x	-0.03	0.6143
ash		y= 4.42-0.001*x	0.10	0.0558
water		y= 88.94-0.022*x	0.27	0.0029

Appendix 2. Regression analysis of body component (g) on the date of collection (x) of mallards overwintering on the North Saskatchewan River in Edmonton, Alberta, 1989/1990.

Component	Sex-age	Regression equation	r^2	P
lipid		y=193.64-1.31*x	0.23	0.0462
protein	AF	y=144.29+0.02*x	-0.08	0.9458
ash		y= 26.30+0.04*x	-0.03	0.4626
water		y=609.97-1.18*x	0.11	0.1377
lipid		y=147.99-1.01*x	0.180	0.0072
protein	JF	y=130.62-0.11*x	-0.020	0.5293
ash		y= 28.85-0.03*x	-0.004	0.3580
water		y=586.09-0.81*x	0.090	0.0494
lipid		y=303.78-2.79*x	0.63	0.0001
protein	AM	y=228.90-0.85*x	0.45	0.0014
ash		y= 39.67-0.09*x	0.12	0.0835
water		y=680.09-0.99*x	0.12	0.0858
lipid		y=218.80-1.87*x	0.41	0.0002
protein	JM	y=184.10-0.66*x	0.14	0.0273
ash		y= 33.58-0.06*x	0.04	0.1459
water		y=735.29-1.88*x	0.21	0.0087

Appendix 3. Regression of body component (g) on live weight (x) of mallards overwintering in Edmonton, Alberta, 1989/1990.

Component	Sex-age	Regression equation	r^2	P
lipid	FA	y=-255.09+0.37*x	0.63	0.0007
protein		y= 68.20+0.08*x	0.10	0.1557
ash		y= 21.69+0.01*x	-0.04	0.4587
water		y= 68.73+0.47*x	0.76	0.0001
lipid	FJ	y=-367.02+0.46*x	0.69	0.0001
protein		y= 4.29+0.12*x	0.22	0.0030
ash		y= 9.06+0.02*x	0.14	0.0176
water		y= 324.44+0.22*x	0.11	0.0286
lipid	MA	y=-375.11+0.43*x	0.80	0.0001
protein		y= -7.98+0.16*x	0.85	0.0001
ash		y= 8.38+0.02*x	0.44	0.0016
water		y= 327.78+0.25*x	0.52	0.0005
lipid	MJ	y=-345.29+0.40*x	0.62	0.0001
protein		y= -14.91+0.14*x	0.22	0.0063
ash		y= 12.66+0.02*x	0.11	0.0507
water		y= 53.21+0.50*x	0.52	0.0001

Appendix 4. Predicted lipid and protein levels of mallards captured, banded, and released in early winter and early spring in Edmonton, Alberta, 1989/1990.

Time	Sex-age	Body weight (g: x̄±SE, N)	Fat (g)	Protein (g)
Nov.20-Dec.5 Feb.9-Mar.15	FA	1263 (1) 884.82±20.96 (11)	212.22 72.29	169.24 138.99
loss		30%	66%	18%
Nov.20-Dec.5 Feb.9-Mar.15	FJ	1072.44±34.65 (18) 821.09±11.63 (68)	126.30 10.68	132.98 102.82
loss		23%	92%	23%
Nov.20-Dec.5 Feb.9-Mar.15	MA	1387.00±41.90 (5) 1003.35±15.74 (49)	221.30 56.33	213.94 152.56
loss		28%	75%	29%
Nov.20-Dec.5-Mar.15	MJ	1215.94±23.54 (52) 948.35±11.06 (93)	141.09 34.05	155.32 117.86
loss		22%	76%	24%

Appendix 5. Combined wet weights (g: $\bar{x}$±SE; N) of two kidneys of mallards collected in Edmonton, Alberta, between early winter, 1989 and early spring, 1990.

	Adult		Juvenile	
Time[a]	Female	Male	Female	Male
I	7.83 (1)	9.85±0.56 (3)	8.37±0.71 (7)	8.40±0.82 (7)
II	6.43±0.38 (5)	9.74±0.31 (4)	7.89±0.34 (11)	8.44±0.52 (7)
III	8.24±0.76 (5)	8.77±0.70 (5)	7.02±0.80 (5)	8.44±0.69 (7)
IV	6.10±0.60 (6)	7.67±1.02 (5)	6.73±0.40 (9)	8.53±0.63 (6)

[a] See text for exact dates.

Appendix 6. Wet weights (g: $\bar{x}$±SE; N) of gonads of mallards collected in Edmonton, Alberta, between early winter, 1989 and early spring, 1990.

	Adult		Juvenile	
TIME[a]	Female	Male	Female	Male
I	0.16±0.00 (1)	0.17±0.01 (3)	0.18±0.03 (7)	0.09±0.01 (7)
II	0.18±0.03 (5)	0.24±0.04 (4)	0.17±0.02 (11)	0.10±0.01 (7)
III	0.32±0.06 (5)	0.35±0.10 (5)	0.23±0.01 (6)	0.12±0.01 (7)
IV	0.31±0.05 (6)	0.21±0.04 (5)	0.24±0.04 (9)	0.14±0.02 (6)

[a] See text for exact dates.

Appendix 7. Gizzard wet weights (g: $\bar{x}$±SE; N) of mallards in Edmonton, Alberta, between early winter, 1989 and early spring, 1990.

	Adult		Juvenile	
Time[a]	Female	Male	Female	Male
I	–	–	35.29±1.76 (5)	41.40±2.58 (5)
II	21.45±4.01 (3)	41.29±2.49 (3)	33.45±1.70 (10)	34.98±4.46 (6)
III	31.74±1.88 (4)	37.49±0.75 (3)	32.15±1.22 (5)	37.73±2.59 (7)
IV	30.67±1.64 (4)	35.66 (3)	34.61±1.52 (8)	42.17±1.23 (5)

[a] See text for exact dates.

Appendix 8. Grit content (g: $\bar{x}$±SE; N) of mallards in Edmonton, Alberta, between early winter, 1989 and early spring, 1990.

	Adult		Juvenile	
Time[a]	Female	Male	Female	Male
I	4.95±0.00 (1)	7.99±1.47 (3)	7.34±1.50 (5)	9.32±1.56 (7)
II	2.92±0.34 (5)	4.61±1.09 (4)	5.70±0.88 (9)	5.41±0.74 (6)
III	4.26±0.69 (5)	4.35±0.59 (5) *	6.10±1.33 (6)	5.30±1.08 (7)
IV	5.12±1.01 (6)	8.19±0.83 (5) *	4.96±0.33 (9)	6.96±1.28 (6)

[a] See text for exact dates.
* Means differ significantly ($P<0.05$) within sex-age class.

Appendix 9. Liver wet weights (g: $\bar{x}$±SE; N) of mallards in Edmonton, Alberta, between early winter, 1989 and early spring, 1990.

	Adult		Juvenile	
Time[a]	Female	Male	Female	Male
I	26.25±0.0 (1)	44.64±3.31 (3)	34.39±3.99 (7) *	35.59±3.75 (7)
II	25.46±2.65 (5)	31.80±2.07 (4)	25.40±1.13 (11)	26.87±0.99 (7)
III	29.85±2.72 (5)	36.77±3.51 (5)	27.94±2.03 (5)	31.42±1.44 (7)
IV	25.17±2.61 (6)	33.95±5.57 (5)	24.65±1.17 (9)	32.25±1.43 (6)

[a] See text for exact dates.
* Mean significantly different ($P<0.05$) from other means within sex-age class.

Appendix 10. Molt intensity score ($\bar{x}$±SE; N) of mallards in Edmonton, Alberta, between early winter, 1989 and early spring, 1990.

	Adult		JUVENILE	
Time[a]	Female	Male	Female	Male
I	0.00 (1)	0.40±0.06 (3) *	0.92±0.29 (5)	0.50±0.20 (2)
II	0.65±0.15 (2) *	0.00 (1)	1.20±0.47 (3)	0.45±0.18 (4)
III	0.80 (1)	0.15±0.15 (2)	0.50±0.00 (2)	0.30 (1)
IV	0.23±0.03 (4) *	0.05±0.05 (4) *	0.76±0.39 (9)	0.68±0.10 (6)

[a] See text for exact dates.
* Means within sex-age group significantly different ($P<0.05$).

Appendix 11. Body composition analysis-procedure outline

General procedure	Time schedule
I. CARCASS PREPARATION	
1. Preparation for autoclaving	day 1
2. Autoclaving	min. 6 hours (over night)
II. SAMPLE PREPARATION	
1. Carcass homogenization. Obtaining representative sample.	day 2
2. Freezing samples	day 3-5
3. Freeze-drying frozen samples	day 6-11
4. Grinding freeze-dried samples	day 12
III. SAMPLE COMPOSITION ANALYSIS	
1. Lipid content (Goldfish method)	extraction 4 hours *
2. Protein content (Kjeldahl method)	**
3. Dry matter content	min. 6 hours *
4. Ash content	min. 6 hours *
IV. CALCULATION OF ERROR BETWEEN DUPLICATE SAMPLES	
V. CALCULATION OF BODY COMPOSITION-SPREADSHEET	

* time of samples preparation not included
** details included in method description

I. CARCASS PREPARATION

1. Preparation for autoclaving

1.1 Equipment:

steal cans (ca. 5 liter each)

ca. 3000g balance

aluminium foil

beaker 200 ml

tap water

1.2 Procedure:

a) weigh empty can (each can should be individually numbered)

b) pour 200 ml of water into the can and record the weight

c) put whole, thawed bird with feathers into the can

d) record the weight of the can with bird and water

e) cover each can with aluminium foil and perforate the surface

2. Autoclaving:

Set the temperature at 250°C, use liquid cycle, and autoclave for min. 6 hours.

Sample data sheet for autoclaving

Note: because of the detailed description of column titles the format of the actual data sheets has been changed to allow more space for required information.

Column no.	Data recorded
1	Can number
2	Bird identification number
3	Weight of can before autoclaving
4	Weight of can+water before autoclaving
5	Weight of can+bird+water **before** autoclaving
6	Weight of can+bird+water **after** autoclaving

7 Wet weight of sample A in container without lid *

8 Wet weight of sample B in container without lid *

9 Dry weight of sample A after freeze-drying *

10 Dry weight of sample B after freeze-drying (if required) *

* The required procedures are explained below

II. SAMPLE PREPARATION

1. Carcass homogenization. Obtaining representative sample.

1.1 Equipment:

300 ml plastic containers with lid (two for each bird)
permanent marker
min. 400g balance
commercial blender
large bowl
rubber gloves
300 ml container for scooping the homogenate

1.2 Procedure:

a) mark plastic containers (two for each bird) with the following information: run number, bird identification number, symbol A for first sample and symbol B for a duplicate. For example: I-540-A and I-540-B.

b) remove the aluminium foil from the top of the cans

c) weigh each can and record the weight of the can, water, and bird after autoclaving

d) transfer the content of the can into a commercial blender and homogenate for two minutes (adjust time to obtain maximum homogeneity if required)

e) pour the homogenated mixture into a bowl

f) with one hand mix the homogenate while with the other scoop some mixture (make sure you have reached the bottom of the bowl while you were scooping) and transfer into the previously prepared plastic containers (A and B). The plastic containers should be 2/3 filled with homogenate.

g) record the weight of each sample (A and B) without the lid

h) cover each container with lid

2. **Freezing samples**

a) place all containers into the freezer for three days

3. **Freeze-drying frozen samples**

a) remove samples A from a freezer (keep samples B as a reserve)

b) replace plastic lids with aluminium foil and perforate the surface

c) place the containers in freeze-dryer

d) freeze-dry for 5 days or until the samples reached constant weight

e) remove samples from the freeze-dryer

f) record the weight of each sample without cover

4. **Grinding freeze-dried samples**

4.1 Equipment:

home blender

4.2 Procedure:

a) transfer whole sample into the blender and grind the sample

b) return whole sample into its original container

Note: store samples in the fridge for further analysis

III. SAMPLE COMPOSITION ANALYSIS

Note: for each run in body composition analysis prepare a "blank" sample to eliminate other factors, not associated with sample, which could influence the results of the analysis.

1. Lipid content:

In this analysis the lipids are dissolved in petroleum ether and collected in extraction beaker. After the solvent is evaporated the lipid residue is weighed.

1.1 Reagents:

Petroleum ether (30-60°C boiling point)

1.2 Equipment:

Goldfish apparatus

extraction beakers

aluminium or glass thimbles

filter paper no.54

ether collection beakers

glass fibre

analytical balance

spatula

permanent marker

1.3 Procedure:

Note: to prepare the "blank" follow the procedure below step a,b,d-t

a) number each extraction beaker

b) weigh each extraction beaker to the nearest 0.0001g

c) weight ca. 2g sample (in duplicate) from freeze-dried sample A on filter paper

d) fold the filter paper, put small clamp of glass wool on the top to prevent the loss of sample during extraction, and place inside the glass or aluminium thimble

e) place the thimble with sample into extraction beaker

f) install the thimble with sample on extraction apparatus

g) fill the extraction beaker with 40 ml of petroleum ether and attache to the apparatus (repeat step e and f for all samples)

h) turn on condenser water

i) turn on the burner to "high" position

j) extract for four hours

k) turn off the burner and let the beakers cool off

l) remove the extraction beakers from the rack

m) replace the thimbles with ether collection beakers

n) return the extraction beakers to the rack

o) turn on the burner and collect the ether from the extraction beakers for ca.10 min.

Note: check the process frequently to avoid burning the lipids in extraction beakers

p) turn off the burner and let the beakers cool off

q) remove all extraction beakers, cover them with aluminium foil, and perforate the surface

r) place samples into an oven for 30 min at 110°C to evaporate the remaining ether

s) remove beakers and let them cool to a room temperature

t) weigh the extraction beakers to the nearest 0.0001g

u) calculate the lipid content using the following equation

(1) lipid (g) = ((wt. of extraction beaker after extraction (g) - wt. of extraction beaker before extraction (g)) - correction factor

(2) correction factor = wt. of "blank" after extraction (g)- wt. of "blank" before extraction (g)

(3) %lipid = lipid (g) / wt. of sample (g) x 100

Sample data sheet for lipid content

Column no.	Data recorded
1	Sample identification number
2	Extraction beaker number
3	Weight of extraction beaker (empty)
4	Sample weight
5	Weight of extraction beaker after extraction
6	Lipid (g)
7	% lipid

2. **Protein content**

In the protein content analysis the nitrogenous compounds are reduced to ammonia by digestion with sulphuric acid in the presence of catalyst. The digested solution is made basic and the ammonia is collected in boric acid solution by distillation. The amount of ammonia is determined by titration with standard solution of acid.

2.1 Reagents:

catalyst packs (contain 9.9g K_2SO4, 0.41g HgO, 0.08g $CuSO_4$)

concentrated sulphuric acid (H_2SO_4)

4% boric acid (BH_3O_3)

40% sodium hydroxide (NaOH)

0.4819 N sulphuric acid (H_2SO4)

2.2 Equipment:

Kjeldahl apparatus

Kjeldahl flasks (800ml)

erlenmeyer flasks (250ml)

beaker (500ml)

rubber stoppers

spatula

plastic cups (5ml)

magnetic stirrer

2.3 Procedure:

a) number all Kjeldahl flasks

b) weigh out ca. 1g of freeze-dried sample A into a 5ml plastic cup

c) fold the cup and place in 800ml Kjeldahl flask

Note: make sure no sample was lost or stack in the neck of the flask

d) prepare a "blank"

Note: blank is run on an empty cup

e) turn on water in Kjeldahl apparatus

2.3.1. digestion

f) add catalyst pack and 30 ml of concentrated H_2SO_4 to each flask

g) place flasks on digestion rack and turn on the burner to "high" position

h) when content becomes clear or pale green let it digest for another 30 min then turn off the burner and let flasks cool

2.3.2. distillation

i) to each flask add 200ml of distilled or tap water and swirl content until crystals dissolve

j) add ca. 1g of zinc metal

k) fill corresponding number of erlenmeyer flasks with 50ml of boric acid and place under distillation tubes

l) to each Kjeldahl flask add 110ml of sodium hydroxide and place the flasks on the distillation rack

m) turn on burners to "high" position and distil into receiving erlenmeyer flasks until the flasks contain 150ml of distillate

n) turn off the burners and remove the erlenmeyer flasks

2.3.3. titration

o) titrate with 0.4819 N H_2SO_4 until the blue solution in the erlenmeyer flask turns pink

Note: place flask on magnetic stirrer while titrating

p) calculate the %N using the following equation:

(1) $\%N = ((vol.H_2SO_4 - blank) / wt\ sample\ (g)) \times (14mg/m\ mole) \times 0.4819 \times 100\% \times (1g/1000mg)$

2) $\%protein = \%N \times 6.25$

2.4 Preparation of solutions for protein analysis

2.4.1 40% NaOH

Add 412g of Na_2S $9H_2O$ to 6 l of distilled H_2O in glass carboy, mix well with electric mixer until dissolved or add:

a) 223g of 60% NaS to 6 l of H_2O or

b) 178g of K_2S to 6 l of H_2O or

c) 134g of 100% Na_2S to 6 l of H_2O

Then add 20 l of 50% (wt) NaOH and mix for 15 min.

2.4.2 40% boric acid

Dissolve 1,280g of boric acid crystals in distilled water in a glass carboy and bring up to 32 l with distilled water. Weigh 100mg of bromocresol green and 40mg of methyl red and dissolve in 100ml of methanol. Pour the solution into the carboy containing boric acid solution and mix.

2.4.3 Standardized 0.4918 N H_2SO_4

a) add 23.61g of concentrated H_2SO_4 to each 1l of distilled H_2O in glass carboy and mix for 15 min.

b) weigh out 40mg THAM (Tris hydroxy amino methane) into a small erlenmeyer flask and bring up the volume to 50ml

c) add 1 to 2 drops of methyl red alcohol solution

d) titrate to orange-pink end point

e) calculate the normality using the following equation:

$$\text{Normality } H_2SO_4 = \text{wt. of THAM (mg)} / (\text{vol. } H_2SO_4\text{(ml)} \times 121.14\text{mg/ml})$$

Sample data sheet for protein content analysis

Column no.	Data recorded
1	Sample identification number
2	Identification number of Kjeldahl flask
3	Weight of sample
4	Reading from titration
5	% protein

3. Dry matter content

3.1 Equipment:

beakers 50 ml

spatula

analytical balance

oven (110°C)

aluminium foil

3.2 Procedure:

a) number each beaker (use pencil)

b) place all beakers into an oven at 110°C and wait till the temperature stabilize at 110°C

c) remove one beaker, put on the balance and close the door to warm up the compartment. Return the beaker into the oven.

d) remove each beaker individually from the oven and weigh

Note: do not return the weighed beakers to the oven.

e) weigh out ca. 2g (in duplicate) of freeze-dried sample A into each beaker

f) leave one beaker empty as a blank

g) cover beakers with aluminium foil and perforate the surface

h) place the samples into an oven at 110°C for min. 6 hours (preferable over night)

i) before weighing all dried samples warm up the balance compartment

j) remove each sample separately from the oven and weigh to the nearest 0.0001g

Note: to not discard the samples since they will be used later for ash analysis.

k) calculate g and % of dry matter using the following equations:

(1) correction factor = wt. of blank before(g) - wt. of blank after(g)

(2) DM (g) = (wt. of beaker with sample after (g) - wt. of empty beaker (g)) - correction factor (g)

(3) %DM= (DM(g) / wt. sample(g)) x 100

4. **Ash content**

4.1 Equipment:

muffle furnace

4.2 Procedure:

a) place samples (saved from dry matter analysis) in a muffle furnace at 550°C and burn for min. 6 hours (preferable over night)

Note: do not cover the samples

b) turn off the furnace and let it cool to ca. 150°C

c) place the samples in an oven at 110°C

d) before weighing all dried samples warm up the balance compartment by using blank then return the blank to the oven and weigh it after all samples have been weighed

e) remove each sample separately from the oven and weigh

f) calculate ash content using the following equations:

(1) correction factor (g) = wt. of blank before (g)- wt. of blank after (g)

(2) Ash (g) = (wt. of beaker with sample after (g) - wt. of empty beaker (g)) - correction factor (g)

(3) %Ash = (ASH(g) / wt. of sample(g)) x 100

Sample data sheet for dry matter and ash content analysis

Column no.	Data recorded
1	Sample identification number
2	Beaker identification number
3	Weight of empty beaker
4	Weight of sample
5	Weight of beaker and sample after drying
6	Weight of beaker and sample after ashing
7	Dry matter (g)
8	% dry matter
9	Ash (g)
10	% ash

IV. CALCULATION OF ERROR BETWEEN DUPLICATE SAMPLES

Note: if the range between sample and its duplicate do not exceed 5%, then take an average from both measurements and enter into the spreadsheet, otherwise repeat the analysis.

x_1= value of sample 1

x_2= value of sample 2

x_3= mean

$$x_1 + x_2 / 2 = x_3$$

$$\text{Range} = (x_1 - x_2 / x_3) \times 100$$

V. CALCULATION OF BODY COMPOSITION-SPREAD SHEET

Column	Data	Formula
A	Bird ID number	*
B	Sex-age	*
C	Time of collection	*
D	Live weight of bird	*
E	% protein	*
F	% lipid	*
G	% ash	*
H	% dry matter	*
I	100% protein **	E x 100/H
J	100% lipid **	F x 100/H
K	100% ash **	G x 100/H
L	Can+water (before autoclaving)	*
M	Can+water+bird (before autoclaving)	*
N	Weight of bird (before autoclaving)	M-L
O	Can+water+bird (after autoclaving)	*
P	Weight of bird (after autoclaving)	O-L
Q	% of start (gain or loss of weight of bird due to autoclaving)	(P/N) x 100
R	Wet sample (A) in container	*
S	Wet sample (A) without container	R-weight of container

T	Dry sample (A) in container	*
U	Dry sample (A) without container	T-weight of container
V	% of autoclaved	(U/S) x 100
W	% dry matter	copy from H
X	100% dry weight	N x (Q/100)x(V/100)x(W/100)
Y	% dry matter	(X/N) x 100
Z	% water	100-Y
AA	Weight of water	N x (Z/100)
AB	% protein	(I/100) x Y
AC	Weight of protein	N x (AB/100)
AD	% lipid	(J/100) x Y
AE	Weight of lipid	N x (AD/100)
AF	% ash	(K/100) x Y
AG	Weight of ash	N x (AF/100)
AH	% of total	Z+AB+AD+AF
AI	Total weight	AA+AC+AE+AG

* Data from data sheets and sample analysis
** Data corrected to 100% dry matter